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IN THIS ISSUE

Because climate change is becoming an increasingly urgent concern, it is important to understand its diverse effects on the natural world. These impacts are often particularly noticeable at the edge of the natural ranges of species. The first article in this issue studies the impact of climate change on an isolated black spruce stand at the southernmost extent of its range in southern Michigan. The authors conclude that the projected trajectory of its development does not track that of similar stands further north within the main range of the species.

The effect of environmental factors on a local biota is also the subject of the study reported in the second article, but with a different emphasis. In this case, the effect of microhabitat factors on communities of lichens and bryophytes, such as the identity and size of their host tree, the directional location of individuals on the host, and the presence of other epiphytes, is studied.

The *Great Lakes Botanist*, as well as its predecessor, *The Michigan Botanist*, has long been an important publisher of local floras in the Great Lakes area. As time passes and as further exploration is undertaken, older floristic studies become outdated, and updates become essential to maintain the current status of our knowledge. It is therefore with pleasure that we publish a set of additions, by Thomas L. Eddy, to a flora of Green Lake County, Wisconsin, that he published in these pages 22 years ago, in 1996.

Not only are local floras subject to continued exploration, but individual new finds add to our knowledge of the regional flora as a whole. For that reason, the Noteworthy Collections feature of this journal has been, and continues to be, an important source of such new knowledge. This issue features three Noteworthy Collections articles that provides new information about the distribution of six species in the Great Lakes region, all but one native to areas of the Old World, and one with a primary distribution in the southern portion of the United States that has recently been discovered for the first time in Ohio and Michigan.

—Michael Huft

AGE AND STRUCTURE OF A *PICEA MARIANA* STAND AT THE SOUTHERNMOST EXTENT OF ITS RANGE IN SOUTHERN MICHIGAN

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ABSTRACT

Climate change has begun to cause shifts in the distributions of tree species, particularly those in northern latitudes. Because such shifts have largely consisted of contractions at the southern limits of the range of a species, understanding the structure and development of forests at the southernmost extent of a species' distribution is important for identifying the impacts of climate change. We studied stand structure, stand history, and current regeneration of a small stand dominated by *Picea mariana* (Mill.) Britton, Sterns & Poggenb. (black spruce) in southeastern Michigan. The composition and structure of the overstory, understory, and ground cover layers were recorded, and the diameter, height, and age of selected individuals of *P. mariana* were measured. The stand was nearly monotypic, dominated by *P. mariana* in all layers but the ground cover. We estimate the stand to be even-aged, approximately 70 years old, and likely to have been established after a stand-replacing fire in the early 1940s. The stand lacked the significant regeneration that has been documented for *P. mariana*-dominated forests at higher latitudes, either by seed or by layering; we speculate that most tree establishment occurred in the first two decades following the fire until an unfavorable seedbed of *Sphagnum* moss developed that limited further recruitment of tree seedlings. We expect that in the absence of fire the stand will not transition from an even- to an uneven-aged stand, as is typical for *P. mariana* in the boreal forest, and its successional trajectory remains unclear. Understanding how forest development varies for species at their southernmost extent is critical for differentiating the future effects of climate change, and further study is therefore needed to document the forest dynamics of *P. mariana* in such locations.

KEYWORDS: Mud Lake bog, black spruce, peatland forests, forest dynamics

INTRODUCTION

One of the most prominent topics of interest to ecologists today is the potential impact of climate change on the distribution of species. Researchers have documented significant shifts in the range of tree species in several regions of the United States where increases in mean annual temperature have been most substantial, such as the Northeast and the Upper Midwest (e.g., Zhu et al. 2011). The process of the change in distribution remains unclear, however. Iverson et al. (2004) predicted that the centroid of suitable habitat of 134 tree species in the eastern US could migrate as much as 800 km, and Woodall et al. (2009) documented a northward shift for many northern species. Zhu et al. (2011) found lit-

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tle evidence for northward migration of tree species, but their data suggested that the ranges of tree species tend to contract with climate change, particularly at the southern border. Other studies have also suggested that the ranges of eastern tree species in the United States tend to contract from the south without expanding to the north as climate change progresses (e.g., Murphy et al. 2010). Understanding the dynamics of forest stands dominated by species at the southern extent of their range is therefore important for predicting the persistence of such species and their potential for range contraction.

Picea mariana (Mill.) Britton, Sterns & Poggenb. (black spruce) is widespread in the North American boreal forest, where it often dominates forests on cool and nutrient-poor soils (Rowe 1972; Van Cleve and Viereck 1981). It reaches the southern extent of its distribution in North America in southern Michigan and Wisconsin, Pennsylvania, and New Jersey (Little 1971), where it is typically limited to low-lying, cold, wet ecosystems on organic soils such as bogs and other peatlands (Cohen and Kost 2008). Forests dominated by *Picea mariana* often originate from stand-replacing fires, which kill previously established trees and release seeds from semi-serotinous cones, resulting in even-aged postfire stands (Greene et al. 1999; Charron and Greene 2002; Bouchard et al. 2008; Rossi et al. 2009).

The growth form of *Picea mariana*, characterized by low branches that act as "ladder fuels" between the ground and the canopy, facilitates stand-replacing crown fires (Johnson 1992), and the species depends on the recruitment of post-fire seedlings to dominate stands over long time periods. Most seedlings establish in the first 5–10 years after a fire (Johnson and Fryer 1989); post-fire recruitment and subsequent succession depend strongly on the availability of seeds and the quality of the seed bed (Greene et al. 1999; Johnstone and Chapin 2006), because seedling establishment is often limited by the presence of *Sphagnum* moss on the soil surface. In the absence of additional stand-replacing fires, or where the interval between such fires exceeds the lifespan of the trees, canopy gaps develop after perhaps 120 years (Johnson 1992; Harper et al. 2004; Pham et al. 2004; Rossi et al. 2009), and the stand becomes multi-aged as new cohorts develop in the gaps. Multi-aged *P. mariana* stands are common in northeastern North America (Boucher et al. 2003).

We examined a small stand dominated by *Picea mariana* in southeastern Michigan with the objectives of determining stand history, describing current stand structure and growth, documenting current regeneration, and predicting the future development of the stand. *Picea mariana* stands have been extensively studied in northern latitudes closer to the center and northern extent of their distribution (e.g., Black and Bliss 1980; Bonan and Sirois 1992; Rossi et al. 2009; Tremblay et al. 2011), but fewer data exist that describes *P. mariana* stand structure and development following fire at its southern limit (but see Bonan and Sirois 1992; Locky et al. 2005), and none for southern Michigan. Regional studies of plant and forest communities in peatlands are needed because of the wide variability evident in this wetland type across North America (Jeglum 1991; Locky et al. 2005). Although early descriptions of *P. mariana* stands in southern Michigan exist (Pennington 1906), rapid climate change in the 20th century has necessitated re-analysis of forest types at their southern limits for the purposes of

assessing local conservation efforts as well as of further contributing to our understanding of climate change impacts on these populations of forest tree species.

METHODS AND MATERIALS

Study Area

The *Picea mariana* stand encompasses approximately 0.7 ha directly northeast of Mud Lake in Livingston County in southeastern Michigan (42°24′56″ N, 83°47′30″ W). Mud Lake is a glacial kettle lake, lying low in the landscape and subjected to cooler temperatures than the surrounding uplands, and is likely a former arm of nearby Independence Lake that has been isolated by extensive peat deposition (Pennington 1906; Cohen and Kost 2008). Other small, isolated populations of *P. mariana* are scattered around the region, but the stand at Mud Lake is likely to be the largest in the area where *P. mariana* is the dominant overstory species. The stand is located on thick, acidic, organic (peat) soils and lies approximately 75 m from a floating *Sphagnum* mat that surrounds Mud Lake. The forest floor in the stand itself is dominated by *Sphagnum* mosses and exhibits significant microtopography as hummocks and hollows (Figure 1; Heinselman 1963; Halsey and Vitt 2000). *Sphagnum* mosses sustain wet, cold, acidic, low-nutrient conditions that slow decomposition and facilitate the further development of peat (Halsey and Vitt 2000; Cohen and Kost 2008). The bog mat directly south of the stand supports ericaceous shrubs, including *Vaccinium corymbosum* L. (highbush blueberry), *Chamaedaphne calyculata* (L.) Moench (leatherleaf), and *V. oxycoccos* L. (small cranberry), as well as *Typha* spp. (cattail), and has little or no tree canopy cover. The forest otherwise

FIGURE 1. Interior of the *Picea mariana* stand near Mud Lake, Livingston County, southeastern Michigan, exhibiting heavy dominance by *P. mariana* and a *Sphagnum*-covered forest floor. Photograph by Dan Kashian, September 28, 2010.

surrounding the stand is dominated by *Larix laricina* (Du Roi) K. Koch (tamarack) and hardwoods including *Betula alleghaniensis* Britt. (yellow birch), *Acer rubrum* L. (red maple), and *Ulmus americana* L. (American elm); *L. laricina* is most common to the west of the stand. Pennington (1906) reported that the entire area around Mud Lake was subject to the removal of individual trees for Christmas trees and fenceposts at the turn of the 20th century and was burned by large, severe fires in 1856 and 1888.

Field Sampling and Analysis

The *Picea mariana* stand was sampled using six contiguous 10 × 20 m (200 m^2) plots; the plots were located at least 20 m from the edges of the stand. Within each plot, all live and dead overstory trees ≥ 1.5 cm diameter at breast height (DBH; breast height = 1.4 m) were identified to species, counted, and measured for DBH. Live trees and shrubs measuring 1.5–9.0 cm DBH were classified as understory, and those ≥ 9.1 cm were classified as overstory. All live woody groundcover species (< 1.5 cm DBH and those < 1.4 m tall, regardless of DBH) were tallied by species within four 0.5 × 8 m belt transects (16 m^2 total) in each plot, extending from each corner of the plot along the long axis of the plot boundary. Other than *Sphagnum*, herbaceous vegetation was virtually absent in the stand and was not sampled. The stem density of all three forest strata was determined by converting stem counts in each plot to stems/ha. Relative density (number of stems of a species / number of stems of all species) was calculated for overstory, understory, and ground cover species. Relative dominance (basal area of a species / basal area of all species) was calculated for overstory trees.

Tree height was determined with a clinometer for five randomly selected *Picea mariana* trees in each plot (n = 30 trees), estimated to the nearest 0.25 m. The abundance of coarse woody debris (fallen dead wood) was estimated using the planar intercept method along 5 non-overlapping 15.2 m transects (76 m total transect length for the stand), as described by Brown (1974). The age of each *P. mariana* overstory tree that stood within four meters of each plot corner and the 10 m mark of the long axis of each plot (n = 156 trees) was determined using an increment core extracted 30 cm from the ground. Prior to determining the age, the cores were mounted and sanded using standard techniques (Speer 2010), and annual rings were measured to the nearest 0.01 mm using a sliding bench micrometer. The relationship between tree age and diameter was modeled using the Michaelis-Menten function (y = a*x/b+x), where y = age, x = diameter, and a and b are parameters. The Michaelis-Menten function is most appropriate for ecological data that increase to an asymptote from the origin (Cardinale et al. 2006). The site index of the stand was calculated using overstory tree height and age plotted on site index curves developed for *P. mariana* in northeastern Minnesota (Carmean et al. 1989) and on peatlands in northern Ontario (Payandeh 1978).

RESULTS

Picea mariana represented 99.2% of the overstory trees in the stand; other overstory species included three stems of *Larix laricina* (0.5%) and a single stem of *Betula alleghaniensis* (0.3%). Picea mariana was the only overstory tree in four of the six plots, where its density ranged from 1350 to 2050 stems/ha (1775 stems/ha for the stand). The total basal area for the stand was 28.22 m^2/ha, 97.8% of which was attributable to *P. mariana*, 1.4% to *L. laricina*, and 0.8% to *B. alleghaniensis*. *Picea mariana* was less dominant in the understory, but still composed 72.1 % of that layer at a density of 792 stems/ha; *L. laricina* (17.1%), *B. allegheniensis* (10.1%), and *Quercus rubra* L. (red oak; 0.6%) were the other species present. The understory overall was quite sparse, with a density of 1150 stems/ha for all species combined. The woody groundcover was also sparse and was dominated by *Vaccinium corymbosum* (79.6%), especially in the southern portion of the stand closest to Mud Lake. *Acer rubrum* and *B. alleghaniensis* were also present in the ground cover, but represented less than 10% of the

TABLE 1. Density (stems/ha) of overstory, understory, and ground cover in each of six plots and in the stand as a whole near Mud Lake, Livingston County, Michigan. Values in parentheses are relative density (%) for the species.

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Stand
Overstory (> 9.0 cm DBH)							
Picea mariana	2050 (100.0)	1900 (100.0)	1800 (98.0)	1900 (100.0)	1650 (100.0)	1350 (93.6)	1775 (99.2)
Larix laricina						150 (7.4)	25 (0.5)
Betula alleghaniensis			50 (2.0)				8 (0.3)
Understory (1.5–9.0 cm DBH)							
Picea mariana	750 (93.8)	600 (85.7)	1000 (80.0)	600 (42.9)	1250 (86.2)	550 (42.3)	792 (72.1)
Larix laricina	50 (6.3)		200 (16.0)	750 (53.6)	100 (6.9)	250 (19.23)	225 (17.1)
Betula alleghaniensis		100 (14.3)	50 (4.0)	50 (3.6)	100 (6.9)	450 (34.6)	125 (10.1)
Quercus rubra						50 (3.9)	8 (0.6)
Ground cover (< 1.5 cm DBH or < 1.35 m tall)							
Vaccinium corymbosum	20750 74.4)	14350 (68.0)	16800 (92.3)	4250 (90.4)	3850 (80.2)	5400 (98.2)	10900 (79.6)
Acer rubrum	2700 (9.7)	4500 (21.3)	450 (2.5)	50 (1.1)	150 (3.1)	50 (0.9)	1317 (9.6)
Betula alleghaniensis	3500 (12.5)	2000 (9.5)	850 (4.7)	50 (1.1)	50 (1.0)		1075 (7.8)
Picea mariana	550 (2.0)	250 (1.1)	50 (0.2)	300 (6.4)	750 (15.6)	50 (0.9)	325 (2.4)
Frangula alnus	300 (1.0)						50 (0.3)
Quercus rubra	100 (0.3)		50 (0.2)	50 (1.1)			33 (0.2)

stems. A few stems of *Frangula alnus* Miller (glossy buckthorn) and *Q. rubra* were also found in the ground cover. *Picea mariana* was not common in the ground cover, representing only 2.4% of the stems (Table 1). We found no evidence of layering by *P. mariana* in our sampling.

The DBH of *Picea mariana* ranged from 2.0 cm to 21.2 cm (coefficient of variation = 40%) with a mean diameter of 11.05 cm, and exhibited no obvious spatial pattern of variation across the six plots (Table 2). The size distribution of *P. mariana* revealed a bell-shaped curve typical of an even-aged stand (Oliver 1981; Johnson 1992), with only a few dead trees that were found mostly in the smaller size classes (Figure 2). Most of the dead trees were *P. mariana* (64%);

TABLE 2. Mean values of diameter at breast height (DBH) (n = 331), height (n = 30), and age (n = 156) of *Picea mariana* in each of six plots near Mud Lake, Livingston County, Michigan, and in the stand as a whole (± one standard error). The n values given above are for the stand as a whole.

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Stand
DBH (cm)	11.54 ± 0.44	11.64 ± 0.60	10.17 ± 0.48	10.44 ± 0.58	9.64 ± 0.58	11.22 ± 0.73	11.05 ± 0.22
Height (m)	12.1 ± 0.61	11.0 ± 0.59	10.7 ± 0.92	10.6 ± 0.61	9.9 ± 1.09	10.6 ± 0.71	10.8 ± 0.32
Age (yrs)	66.2 ± 3.06	68.2 ± 4.37	66.2 ± 2.73	59.4 ± 3.36	49.8 ± 3.68	54.8 ± 2.73	56.1 ± 0.76

Larix laricina constituted 34% of them, and there was one dead stem of *Betula alleghaniensis* (2%). Most of the dead stems of *L. laricina* were found in the center of the stand, where 43% of all dead trees were sampled. The presence of only a few standing dead trees (constituting a basal area of 7.6 m^2/ha) suggested that recent self-thinning has not occurred in the stand, at least among *P. mariana*, which represented 68% of the standing dead basal area. Moreover, fallen dead wood included only 7738 kg/ha of woody debris < 2.5 cm in diameter, and only 4688 kg/ha of woody debris > 7.6 cm in diameter.

Tree height of *Picea mariana* averaged 10.8 m for the stand (coefficient of variation = 16%), ranging between 6.75 and 14.25 m with the tallest trees found closest to Mud Lake (Table 2). The height distribution of *P. mariana* was skewed to the right with most trees being 9 to 12 m tall (Figure 3). The mean age of *P. mariana* in the stand was 56 years (± 0.76 yrs, c.v. = 17%), ranging from 29 to 75 years with the oldest trees occurring in the southern part of the stand nearer Mud Lake (Table 2). The age distribution of *Picea mariana* also approximates a

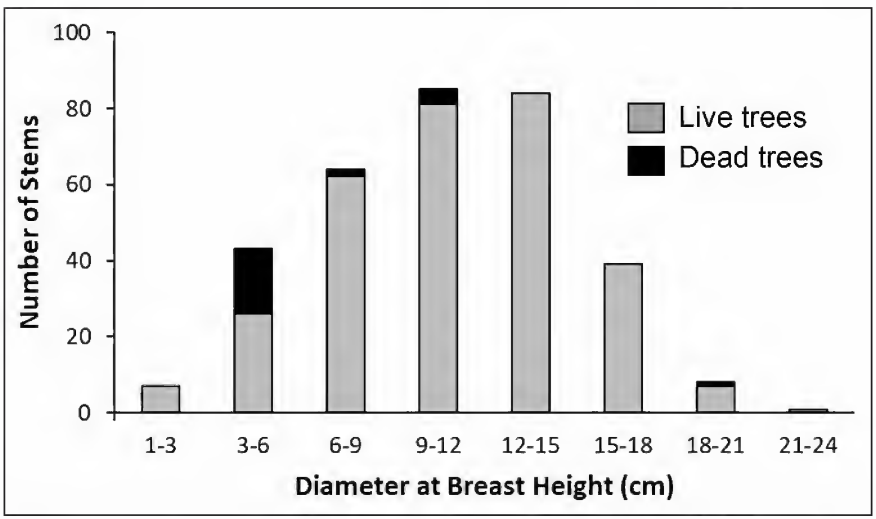

FIGURE 2. Size distribution for all *Picea mariana* trees > 1.5 cm diameter at breast height in the six plots (n = 331). The dark portion of a bar indicates the number of standing dead trees in that size class. The bell-shaped size distribution is characteristic of an even-aged stand.

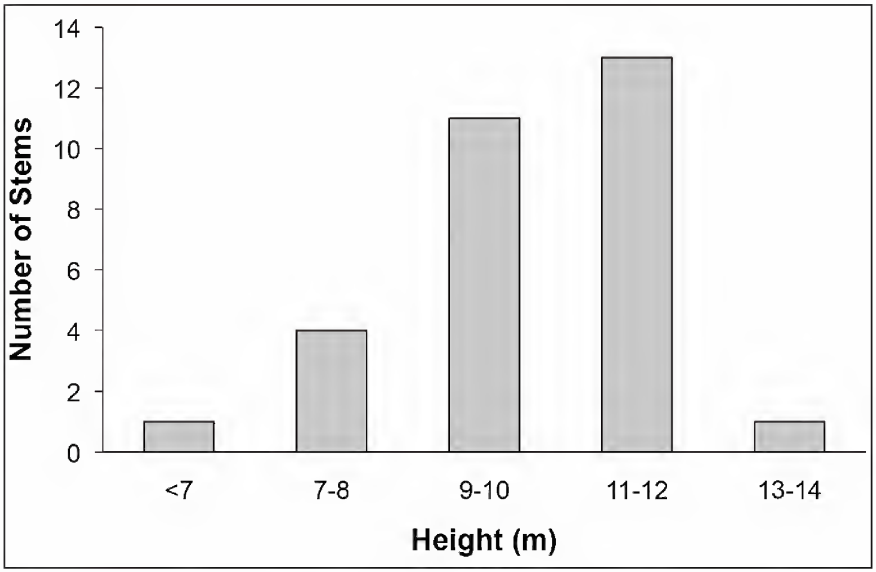

FIGURE 3. Height distribution for 30 randomly-selected *Picea mariana* trees in the six plots.

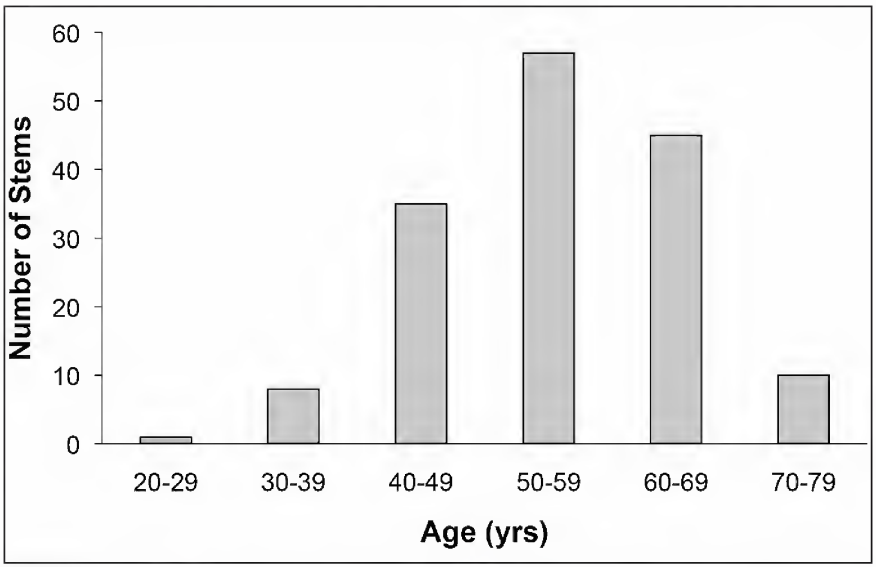

FIGURE 4. Age distribution for 156 randomly-selected *Picea mariana* trees in the six plots. Most of the trees were established in the first 30 years following the fire.

FIGURE 5. Cumulative basal area (m^2) for an average *Picea mariana* tree in the six plots. Solid lines indicate the maximum and minimum cumulative basal area for trees at a given age; the dashed line represents the average (n = 156). The shallow slope of the average basal area growth curve suggests that growth was extremely slow throughout the life of a given tree in the stand.

bell-shaped curve typical of an even-aged stand, with 65% of trees aged 50 to 70 years old and very few young trees in the stand (Figure 4). The site index of the stand was low but within the range of *P. mariana* at northern latitudes (Viereck and Johnston 1990), approximating SI = 10.75. The annual diameter growth of *P. mariana* was highly variable among individual trees, and this variability in growth increased with the age of the tree (Figure 5). The rate of increase of annual growth was very slow, and canopy closure was likely to have been achieved within the first decade following stand initiation. Growth of suppressed trees was nearly zero for almost 35 years after stand initiation, followed by a sudden but slight increase in growth that probably represents a minor growth release by stand age 40 (Figure 5). The Michaelis-Menten model explained only 38% of the variation in the relationship between age and diameter of *P. mariana* (Age = 87.635 *DBH / 6.655 + DBH; $R^2 = 0.38$; $p < 0.001$).

DISCUSSION

The *Picea mariana* stand near Mud Lake is a near-pure, even-aged stand growing on deep organic soil with a heavily *Sphagnum*-covered forest floor that has probable ramifications for stand structure, development, and future persistence. We estimate that the stand originated in the early 1940s, probably following a stand-replacing fire that would have created the opportunity for heavy post-

fire seedling recruitment (Johnstone et al. 2009; Brown and Johnstone 2012). Pre-fire forest composition remains unclear. Pennington (1906) reported the area including the *P. mariana* stand to be a *Larix laricina–P. mariana* community with the two species existing in equal proportions; he also described the area to be recently burned all around Mud Lake based on burned stumps and other evidence, though not in the precise area of the current *P. mariana* stand. We presume the current stand to have originated from a stand-replacing fire with sufficient severity to release *P. mariana* seeds from semi-serotinous cones (Greene et al. 1999) and eliminate *L. laricina*, thereby allowing *P. mariana* to establish and dominate the stand. It is unclear why *P. mariana* is uncommon elsewhere near Mud Lake on organic soils that typically support the species (Harper et al. 2005). Variation in severity of a fire much larger than but including the current stand could explain the local distribution of *P. mariana* if the severity were sufficiently high to incinerate cones and eliminate the seed source (Johnstone et al. 2009), but we have no data to support this possibility.

The *Picea mariana* stand at Mud Lake exhibits many of the characteristics of a classic even-aged stand that result from a stand-replacing fire (Johnson 1992), but it appears to show several structural and developmental trends different from those studied in the boreal forest. Oliver (1981) proposed a general four-stage model for stand development that includes (1) stand initiation dominated by disturbance-created coarse woody debris and high tree establishment; (2) stem-exclusion highlighted by density-dependent mortality (self-thinning); (3) understory re-initiation caused by canopy fragmentation; and (4) old-growth forest with high structural diversity. Oliver's model is a simple representation of stand development that has been broadly applied to many forest types, both deciduous and coniferous (Oliver and Larsen 1990), but has sometimes been found to be less applicable for stands with complex structures or those found on extreme or atypical site conditions (Kimmins 2003). Harper et al. (2005) unsuccessfully applied the model to *P. mariana* on organic soils in northwestern Quebec. Rather than exhibiting four stages of development, stands of *P. mariana* in Quebec exhibited a short period of decomposition of disturbance-created dead wood and a long, continuous period of tree establishment and growth until the stands reached the old-growth stage (Harper et al. 2004; 2005). We suggest that the Mud Lake stand also fails to fit the four-stage model, in that most of the tree establishment occurred in the first 20 years after a stand-replacing fire. We speculate that tree establishment occurred prior to the formation of an unfavorable seedbed that will limit further *P. mariana* recruitment throughout the development and eventual senescence of the stand.

Most obviously, the Mud Lake stand lacks significant regeneration of *Picea mariana* (Table 1). *Picea mariana* is known to be a shade-tolerant species that can survive in the forest understory for more than 100 years (Greene et al. 1999; Rossi et al. 2009). High shade tolerance allows the formation of advanced regeneration—the presence and persistence of seedling and saplings in a stand that can recruit to the overstory to develop a subsequent cohort when gaps form in the current canopy–in part because the cones are semi-serotinous and provide a suitable seed rain once the trees reach reproductive maturity (Greene et al. 1999; Brown and Johnstone 2012). Therefore, lack of regeneration at Mud Lake prob-

ably reflects the unfavorable seedbed in the presence of *Sphagnum* moss, which has been documented to be a major limitation to tree seedling recruitment in stands dominated by *P. mariana* (Johnstone et al. 2009; Brown and Johnstone 2012). The "hummock-hollow" microtopography—present at Mud Lake and typical of mossy ground cover—exposes seedlings to extremely droughty conditions on hummocks and wet conditions in hollows where germination is unlikely (Black and Bliss 1980; Johnstone et al. 2009; Brown and Johnstone 2012; but see Aksamit and Irving 1984). The development of a mossy seedbed also decreases temperature and nutrient availability (Harper et al. 2005). As such, seedling establishment in *P. mariana* often occurs in the first few years following fires prior to the development of a mossy seedbed (Black and Bliss 1980; Greene et al. 1999; Johnstone et al. 2009), as it probably did at Mud Lake. For these reasons, Rossi et al. (2009) reported that vegetative reproduction via layering is favored over the recruitment of seedlings in the decades and centuries after fires for *P. mariana* in the boreal forest; however, layering by *P. mariana* was also absent at Mud Lake.

In addition to the lack of regeneration, the *Picea mariana* stand at Mud Lake appears to lack evidence of self-thinning that presumably would have occurred at the time of canopy closure. Most typically, dead wood in a stand is initially abundant immediately after the disturbance, then decreases but is still common as self-thinning occurs, stabilizing at low abundance, and finally increases again with older tree mortality (Harmon et al. 1986). The amount of dead wood at Mud Lake is extremely low, where 62% of the dead wood is less than 2.5 cm in diameter, and dead wood approximating that resulting from self-thinning was only 4.7 kg/ha, in contrast to *P. mariana* stands in Labrador that contained 9300 kg/ha (Hageman et al. 2009) and in northern Quebec that contained 13530 kg/ha (Boulanger and Sirois 2006). Harper et al. (2005) estimated that self-thinning occurred approximately 40 years after stand initiation in northwestern Quebec, and thus we would ordinarily expect the Mud Lake stand to have experienced stem exclusion already given its age. However, the rate of decomposition at the Mud Lake stand is far too slow to explain its lack of dead wood, even if some fallen dead wood at Mud Lake had been obscured by moss or buried and thereby missed during sampling. Annual growth rings also showed little evidence of self-thinning (Figure 5); we therefore conclude that little self-thinning has occurred in the stand since initial tree establishment.

Given the lack of regeneration and self-thinning at Mud Lake, as well as a lack of layering, we do not expect the stand to develop into a multi-cohort stand typical of the boreal forest (Boucher et al. 2003). At northern latitudes, even-aged *Picea mariana* stands transition to uneven-aged stands as secondary disturbances—typically individual tree deaths that create canopy gaps—occur at small scales and low intensities (Rossi et al. 2009; Tremblay et al. 2011). Such a transition is especially common where the interval between fires is longer than tree longevity (stand age 120–200 years in the northern portions of its distribution; Tremblay et al. 2011). It remains too early in the development of the Mud Lake stand to adequately assess its adherence to Oliver's (1981) model, but its current closed and uniform canopy of co-dominant trees, little fallen or standing dead wood or other evidence of recent self-thinning, lack of regeneration, and a forest

floor heavily carpeted by *Sphagnum* moss suggest that a multi-aged or uneven-aged stand is unlikely to develop. Instead, we speculate that the stand experienced the majority of its tree establishment in the first 20–30 years following a stand-replacing wildfire and that regeneration is now limited by the development of an unfavorable seedbed.

Given the unusual environmental conditions apparently governing stand dynamics of the stand at Mud Lake, it remains difficult to predict the direction of forest succession. One potential successional trajectory is that in the absence of fire the stand will succeed to a deciduous forest as its canopy begins to break up. Such succession would probably be dominated by nearby species able to survive long periods in a seedbed, such as *Betula alleghaniensis* (Greene et al. 1999) and *Acer rubrum* (Lambers and Clark 2005), both of which are abundant within 50 m of the *P. mariana* stand. The likelihood that the stand succeeds to a deciduous forest is uncertain, however, because the aggressive development of *Sphagnum* on deep, acidic organic soils is likely to limit the establishment of deciduous tree species as much as it does *P. mariana.* Although occasional deciduous seedling establishment may occur in such conditions, succession from coniferous to deciduous forest in depressional peatlands is rarely documented (Crum 1992).

The structure and development of *Picea mariana* stands at their southernmost extent is poorly understood (Bonan and Sirois 1992), and our study should serve as one of several that adds to our knowledge in this area. Though the growth of *P. mariana* is considered to be optimal at its southern limit (Bonan and Sirois 1992), our study suggests that stand development may proceed very differently as compared to stands in the heart of its range. Given that southerly stands are likely to be among the earliest responders to climate change, it is important that we are able to differentiate latitudinal variation in stand structure and development from responses to a changing climate if we are to accurately predict the future of *P. mariana* and other boreal species. Replication of our work in other stands at the southernmost extent of *P. mariana* and other boreal species is clearly needed to achieve this goal.

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PERCENTAGE COVER OF LICHENS AND BRYOPHYTES ON THREE HOST TREE SPECIES IN THE UPPER PENINSULA OF MICHIGAN AND NORTHERN WISCONSIN

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ABSTRACT

Although it is well known that lichens and bryophytes can be sensitive indicators of specific microhabitats, it remains less clear how attributes such as host tree identity, tree size, directional location on a tree, and epiphyte co-occurrence impact the degree of lichen and bryophyte colonization. To address these questions, we sampled the percentage cover of lichens and bryophytes on 50 individuals each of *Acer saccharum* (sugar maple), *Pinus resinosa* (red pine), and *Populus tremuloides* (quaking aspen) in a northern hardwoods forest. The samples were taken in 500 cm^2 areas on each tree, 1.5 meters above the ground, in each of the four cardinal directions for a total of 2,000 cm^2 on each tree. Quaking aspen trees had a significantly higher percentage of bryophyte cover than sugar maple, whereas sugar maple had nearly five times more lichen cover than quaking aspen. Lichens and bryophytes were essentially absent (<0.1% cover) on red pine. For sugar maple, percentage cover of lichens was significantly negatively correlated with DBH ($r = -0.30$; $p = 0.036$). The north side of sugar maples had a significantly higher percentage of bryophyte cover than any of the other cardinal directions, and lichen and bryophyte cover were strongly negatively correlated on the north and east sides ($r = -0.48$, $p<0.001$; $r = -0.39$, $p = 0.005$, respectively). Our results demonstrated that the percentage cover of these two life forms varied strongly with host tree and that cardinal location can potentially mediate the degree to which these life forms covary. We suggest that bark chemistry and substrate texture, as well as cardinal directions underlie the patterns found in this study.

KEYWORDS: corticolous epiphytes, lichens, bryophytes, substrate texture, cardinal direction

INTRODUCTION

The effects of microclimate (Campbell and Coxson, 2001) and substrate characteristics (Kuusinen 1995; Löbel and Rydin 2006; Käffer et al. 2016) on lichen and bryophyte abundance are well known; however, the influence of these factors on the biotic interactions between bryophytes and lichens is less well understood. These interactions may mediate the distribution and percentage cover[3] of

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lichens and bryophytes. For instance, certain secondary metabolites produced by lichens completely inhibited the germination of many bryophyte species (Lawrey 1977). Such activity might increase lichen cover or persistence at the expense of competing species. Similarly, Jüriado et al. (2009) reported a significant negative correlation between bryophyte cover and lichen species diversity. Kuusinen (1995) found significantly higher species diversity and cover of bryophytes and lower lichen species diversity on *Populus tremula* than on *Salix caprea*, which suggested that the biotic interplay between epiphyte types impacts their contribution to total cover on different host species.

In addition to interactions among epiphytes, variation in physical and chemical characteristics of individual host trees will also affect the distribution of epiphytes. For example, smooth, homogenous bark, deep fissures, and loose-scaled bark are likely inimical to lichens and other epiphytes (Kuusinen 1995; Löbel and Rydin 2006). Käffer et al. (2016) found that lichen species growing on host trees with smooth bark typically exhibited low species richness and low cover. In contrast, rough bark with a higher water storage capacity typically enhanced epiphyte cover (Levia and Herwitz 2005). Bark pH may provide another axis of niche differentiation, as some epiphytes prefer high pH while others are sensitive to alkaline substrates (Jüriado et al. 2009; Jovan et al. 2012). Additionally, many studies have shown a positive correlation between lichen cover and tree size (diameter at breast height; DBH), as well as basal area (Li et al. 2015; Edman et al. 2007; Johansson and Ehrlén 2003; Dettki and Esseen 1998). This pattern is also consistent with bryophyte cover and DBH (Hazell et al. 1998). Finally, some preliminary work suggests potential impact of cardinal direction on epiphyte cover (Monge-Nájera et al. 2002) and species diversity (Kivistö and Kuusinen 2000). For instance, Monge-Nájera et al. (2002) pooled twenty years of lichen cover data in Costa Rica. Cover values by cardinal orientation were somewhat variable (west 17%, east 14%, north 13%, south 12%). The authors attributed this pattern to climatic variability, as winds in San José move from northeast to southwest and the western sides of trees generally receive less sun and wind during the dry season.

Here, we ask the following questions:

1. Is there a positive or negative relationship between the cover of bryophytes and lichens?
2. To what degree do lichens and bryophytes vary among three common tree species?
3. Does the cover of lichens and bryophytes increase with host size or vary with cardinal direction?

MATERIALS AND METHODS

Location

This study was conducted at the University of Notre Dame Environmental Research Center (UNDERC), located in Land O' Lakes, Wisconsin, during the summer of 2015. Aspen-birch, maple-beech-birch, and spruce-fir forests dominate this relatively undisturbed 3000 ha forest, which straddles the border between Vilas County, Wisconsin, and Gogebic County, Michigan (46°13'N; 89°32'W). This area is part of the hemlock-white pine-northern hardwoods region of the Eastern Deciduous Forest Biome (Delcourt and Delcourt 2000).

Study Species

Three species that commonly occur in northern hardwoods forests clearly represent diversity in bark characteristics that may influence epiphyte diversity and cover, and so were chosen as the focus for this study. The bark of *Pinus resinosa* (red pine) is soft, very loosely attached, and profusely and continuously sloughed off during its life. It is divided by shallow fissures into broad, flat ridges that are covered by thin, loose, light red-brown scales (Culberson 1955). The bark of *Populus tremuloides* (quaking aspen) is thin, often roughened by horizontal bands of circular wart-like excrescences, and frequently marked below the branches by large, dark scars. The bark of *Acer saccharum* (sugar maple) is thick and broken into deep, longitudinal furrows, with the surface separating into small, plate-like scales (Sargent 1961).

Sampling Method

We sampled 50 individuals each of sugar maple, red pine, and quaking aspen. We identified and numbered 30 different sites containing stands of sugar maple and quaking aspen. We then randomly selected 10 of these stands, using a random number generator, and haphazardly selected 5 individuals of each tree from each site. Because red pine was less common and restricted in its local distribution, we haphazardly sampled 25 of these trees at each of two sites. Haphazard sampling was necessary because locations identified randomly within each site did not always meet our sampling requirements. If the randomly selected location did not meet the requirements, we would continue to walk 10 meters in a randomly selected cardinal direction until requirements were met. To ensure independent sampling events, all sampled trees, both within and among species, were at least 10 m apart. We sampled only living trees that were at least 10 cm DBH (exact DBH was recorded for each tree sampled) and that were beneath a closed canopy and at least 40 m from a road or forest edge because edge effects affect epiphyte diversity (Rheault et al. 2003). We sampled lichens and bryophytes using a 10 × 54 cm frame, subdivided into five 10 × 10 cm quadrats (protocol described in Lovadi et al. 2012), to estimate the cover of epiphytic lichens and bryophytes. A smaller (5 × 5 cm) square was used to aid in visual estimations of cover within each 10 × 10 cm quadrat. We vertically placed the frame against each tree trunk 1.5 meters above the ground in each of the four cardinal directions, placing the bottom of the frame at the 1.5-meter mark; thus, a total area of 2000 cm^2 was censused on each tree. If lichen was growing on top of bryophytes, the cover of both bryophyte and lichen visible on the surface was estimated.

Analysis

To calculate cover, the number of cm^2 covered by lichens or bryophytes in each of the quadrats was estimated. These values were then added together to determine the total cm^2 covered by bryophytes or lichens in the sampling area. To determine cover, we divided total cm^2 covered by total sampling area. This process was repeated on each of the four cardinal directions for each tree; average cover per tree was determined by averaging cover of all four cardinal directions.

All statistical analyses were performed using R (R Core Team, 2015). Data were transformed and normalized using the logit function prior to all analyses. A Shapiro-Wilk test was performed to confirm normality ($p > 0.05$). No analyses were done on red pine because lichens and bryophytes were essentially absent. A one-way MANOVA was performed to test for significant differences between the average cover of lichens and bryophytes on sugar maple and quaking aspen trees. We used Pearson correlation coefficients to assess relationships between the average bryophyte and lichen coverage on each tree species, as well as the relationship of each to DBH and cardinal direction. We also used student's t-test to further investigate the relationship between DBH and lichen and bryophyte cover. A repeated measure MANOVA and a series of paired t-tests were used to determine if there was a difference in bryophyte or lichen cover per cardinal direction for both tree species.

RESULTS

Our one-way MANOVA model was significant overall (F=47.7, $p < 0.0001$). Lichens covered three times more area on sugar maple than quaking aspen (F =77.26, p<0.0001; Figure 1). Quaking aspen had higher bryophyte cover than

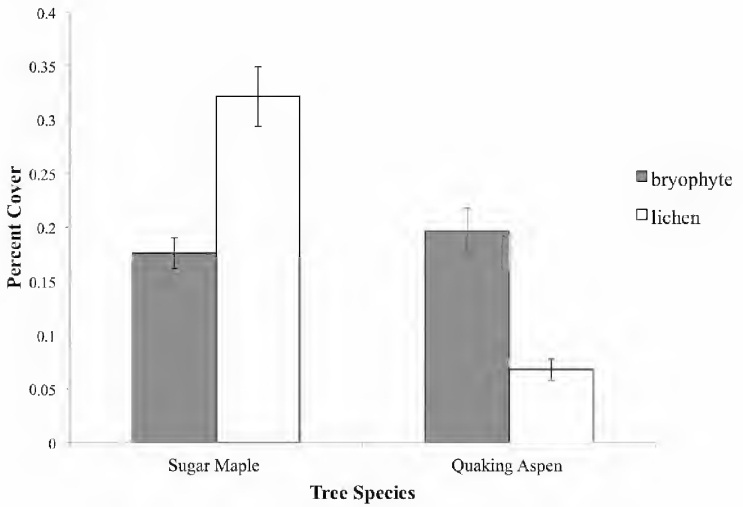

FIGURE 1. Average percentage cover of bryophytes and lichens on 50 sugar maple (*Acer saccharum*) and 50 quaking aspen (*Populus tremuloides*) trees. Error bars represent standard error.

sugar maple, although this pattern was less pronounced than that seen for lichens ($F = 4.51$, $p = 0.036$; Figure 1). Lichens were nearly absent (0.03% cover) and bryophytes never occurred on red pine at our sites (1.5 meters above ground; compare to Figure 1). There was no correlation between bryophyte and lichen cover on quaking aspen ($r = –0.122$; $p = 0.401$; Figure 2); however, they were

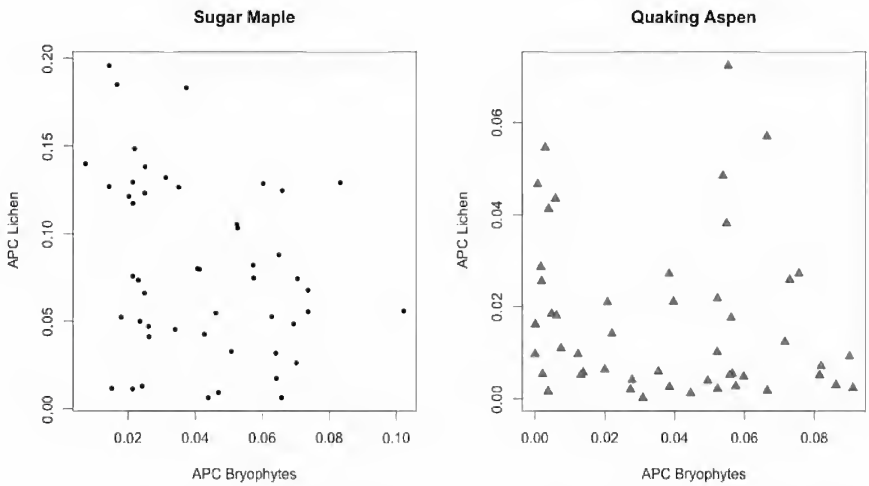

FIGURE 2. Relationship between average percentage cover (APC) of lichens and of bryophytes on sugar maple (each dot represents one tree; r=-0.246; p=0.085) and quaking aspen (each triangle represents one tree; r=-0.122; p= 0.401).

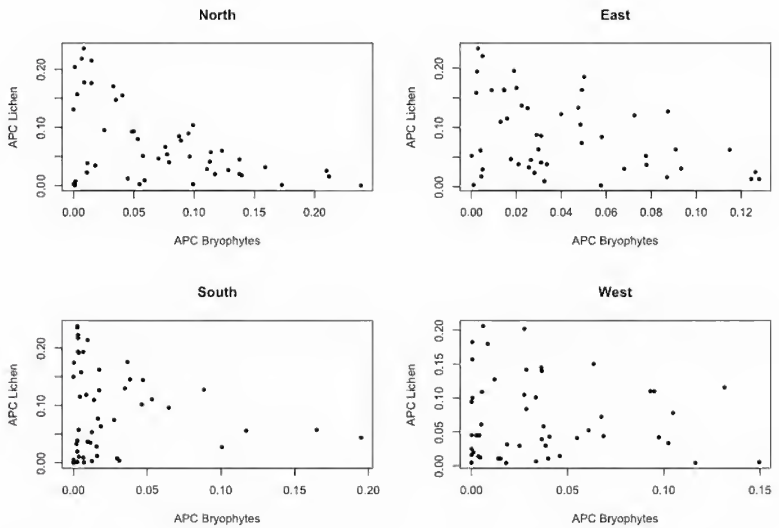

FIGURE 3. Average percentage cover (APC) of lichens and bryophytes on each of four cardinal directions on sugar maple trees (each dot represents one tree). North: r= -0.48, p<0.001. East: r=-0.39, p=0.005. South: r=-0.13, p=0.378. West: r=-0.086, p=0.553.

negatively correlated on sugar maple (r = –0.246; p = 0.085; Figure 2), and this negative relationship strengthened sharply on north facing (r = –0.48, p<0.001) and east facing (r = –0.39, p = 0.005) sides of sugar maple trees (Figure 3). Furthermore, there was a significant difference in bryophyte cover per cardinal direction on sugar maple trees (F = 5.971, p<0.001; Figure 3) overall. Specifically, there was more on the north sides than the south sides (t = 4.14, p<0.0001; Figure 3). No significant relationships were found for cardinal direction and epiphyte cover on quaking aspen (north: r = –0.245, p = 0.09; east: r = –0.207, p = 0.15; south: r = –0.125, p = 0.39; west: r = –0.102, p = 0.48).

Bryophyte cover did not increase with DBH for either sugar maple (r=-0.19; p=0.19) or quaking aspen (bryophyte: r = 0.071; p = 0.62). Lichen cover decreased with DBH on sugar maple (r = –0.30; p=0.036), but not for quaking aspen (r= 0.40; p=0.78). There was a significant difference between the average lichen cover on the ten smallest and ten largest sugar maple trees, (p=0.037), though there was no difference between the ten largest and smallest quaking aspen trees (p=0.76).

DISCUSSION

We found that the overall cover of lichens and bryophytes varies with tree species. It is likely that this variation is related to bark characteristics (Culberson 1955), although the influence of stand-level characteristics, such as the age of

the stand, abundance of large sized trees, and canopy openings (Boudreault et al. 2008), which are often linked to species composition, cannot be ruled out (McCune 1993; Berryman and McCune 2006). Sugar maple, with thicker and rougher bark, has three times the cover of lichens and slightly less bryophyte cover than quaking aspen, with its smooth and homogenous bark. This suggests that these tree species differ in their suitability as substrates. Red pine bark, which lacked epiphytes, is scaly and regularly sloughs off the tree (Sargent 1961), suggesting that this type of bark is not stable enough to allow epiphytes to establish and grow. Indeed, Cáceres et al. (2007) concluded that, at least for tropical trees, lichens need a more stable substrate with "lower degree of shedding."

Lichens are also sensitive to bark attributes other than texture, such as pH (Hauck et al. 2011) and water holding capacity (Levia and Herwitz 2005). Culberson (1955) generated a gradient of bark characteristics that he believed to have strong impacts on cover and host choice of epiphytic vegetative communities found on several focal tree species, including red pine. Red pine ranked the least suitable for colonization in hardness, water holding capacity, and pH, whereas members of the genera *Acer* and *Populus* were ranked the most suitable for colonization. Thus, at least for our three tree species, the system developed by Culberson (1955) predicted the relative lichen and bryophyte cover that we found; to our knowledge, few other studies have explored this possibility (Jüriado et al. 2009). Our findings suggest that Culberson's approach, developed more than 60 years ago, retains its utility and should be more widely applied and expanded to further elucidate underlying mechanisms.

We found a negative relationship between bryophyte and lichen cover on sugar maple, the magnitude of which varied with cardinal direction. As bryophytes often prefer locations with more shade and moisture, and lichens can typically withstand harsher climatic conditions (e.g., more exposure to wind and sunlight), this relationship may be a result of the different climatic conditions at each cardinal direction. The north sides of trees likely receive less sunlight and thus potentially make bryophytes stronger competitors than lichens on the north side. However, we also saw negative correlations between lichen and bryophyte abundance on the east side of sugar maple trees. Additionally, no significant relationships between bryophyte and lichen cover were found on any cardinal direction of quaking aspen hosts. These results suggest that the level of competition between lichens and bryophytes may depend on both the host species as well as the directional location of the epiphytes on the host. Furthermore, the level of competition may vary depending on the specific species involved. Because little research on the influence of cardinal direction on lichen-bryophyte interactions has been published, our results suggest this as an intriguing direction for future studies.

Tree size (DBH) in sugar maple had no discernible effect on bryophyte cover and only a modest negative correlation with lichen cover, in contrast to previous studies that have shown positive correlations between lichen cover and DBH, as well as basal area, on a variety of tree species (Li et al. 2015; Edman et al. 2007; Monge-Nájera et al. 2002; Johansson and Ehrlén 2003; Dettki and Esseen1998). The lack of stronger correlations in this study is likely due to a relatively small

variation in maximum diameter in the stands studied (ranging from 15cm to 41.2cm in sugar maple and from 15.4 cm to 39.1 cm in quaking aspen).

Overall, these variation patterns suggest that interactions among lichens and bryophytes may be substrate-specific and fairly nuanced, as they are for lichen-lichen interactions (as described in Armstrong and Welch 2007). We propose that these lichen-lichen interactions could be used in future studies to describe the relationship between corticolous bryophytes and lichens. Additionally, lichen-bryophyte interactions may be species-specific (e.g., Colesie et al. 2012; Jüriado et al. 2012), a possibility not fully addressed in the current study. Future research exploring these interactions on a species-specific level would greatly improve our understanding of the nuanced patterns seen here.

Understanding the dynamics of lichen-bryophyte interactions provides further insight into early successional stages of ecosystems and nutrient cycling in all forest types. Future study should generate controlled experiments, as there are climatic factors involved at a microscopic scale in the development of both bryophytes and lichens that are challenging, if not impossible, to delineate in a field setting. Given that lichen-bryophyte interactions are likely to develop slowly over time (although there is potential for faster development with fast-growing species such as quaking aspen), further research evaluating these important relationships will require long-term studies using larger sample sizes and experimental approaches. We also suggest that these interactions be analyzed on a species-specific level, and across multiple temporal and spatial scales (exploring both substrate and stand level characteristics) to more fully understand their complex nature.

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ADDITIONS TO THE VASCULAR FLORA OF GREEN LAKE COUNTY, WISCONSIN

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ABSTRACT

The main feature of this report is an addendum to a catalog of vascular plants for Green Lake County, Wisconsin. Published in 1996, *A Vascular Flora of Green Lake County, Wisconsin* documented 921 uncultivated vascular plants based largely on voucher specimens collected from 1979 to 1996 and housed in the Neil A. Harriman Herbarium (OSH) at the University of Wisconsin-Oshkosh. Since 1996, the author has documented an additional 164 species previously unreported for Green Lake County, for a total of 1085 species in the county. Currently, the county flora includes 33 species listed on Wisconsin's Threatened and Endangered Species List.

KEYWORDS: Green Lake County, vascular flora, catalog, addendum

INTRODUCTION

Twenty-two years ago, the author published *A Vascular Flora of Green Lake County, Wisconsin* (Eddy 1996), which reported 921 species of vascular plants growing without cultivation in Green Lake County, Wisconsin. Green Lake County is located in east-central Wisconsin (Figure 1). A majority of the records reported in Eddy (1996) were based on voucher specimens deposited in the Neil A. Harriman Herbarium at the University of Wisconsin–Oshkosh (OSH) that were collected from 1979 to 1996. These records include 31 species of pteridophytes, 8 of gymnosperms, 283 of monocots, and 599 of dicots (Eddy 1996).

Among sources that have contributed to county records since 1996 are systematic studies of the local flora by the author (Eddy 1999, 2001, 2005a, 2005b, 2006, 2007), ongoing collecting by other individuals, and plant records accessed via the internet.

METHODS AND MATERIALS

A county record is defined for purposes of this article as a voucher specimen collected and deposited at OSH or other herbaria in Wisconsin that provides physical evidence that a non-cultivated species is growing or has grown spontaneously in Green Lake County. In addition to OSH records, there are multiple vouchers present elsewhere, notably UW-Madison (WIS), as well as other herbaria in the state. These are cited in the web-based Online Virtual Flora of Wisconsin (OVFW) (OVFW 2018) and are reported in Appendix 1 in addition to the OSH records.

A useful feature of the OVFW is a list of Wisconsin county checklists that are based on vouchered herbarium specimens in the statewide database. The OVFW checklist for Green Lake County, as well as other counties, can be accessed to view scanned herbarium sheets and label data. In 2016, OSH specimens from throughout Wisconsin have begun to be digitized and entered into the OVFW database.

In order to retain nomenclatural uniformity with the 1996 catalog of species (Eddy 1996), names

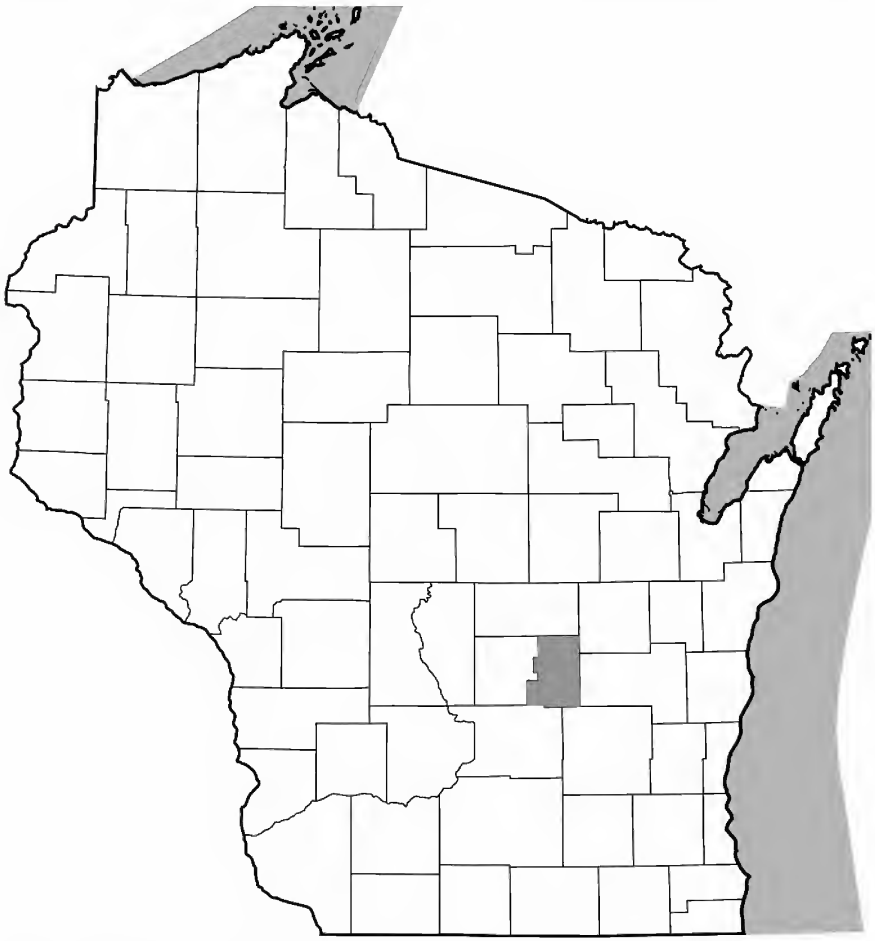

FIGURE 1. Green Lake County, Wisconsin (shaded). Map from Wikipedia Commons, the free media repository.

in Appendix 1 follow Gleason and Cronquist (1991). However, the currently accepted name as used in the OVFW database is indicated in brackets whenever it differs from Gleason and Cronquist (1991), both in Appendix 1 and in the text of this article. The updated nomenclature is based on a number of sources, according to Dr. Mary Ann Feist, Herbarium Curator at UW Madison: Voss and Reznicek (2012), the latest Flora of North America volumes, and recent monographs (personal communication, 30 January 2017).

RESULTS

Since 1996, 164 county records have been added to the county flora. These are listed in Appendix 1. To date, the county flora is represented by 1085 species,

458 genera, and 129 families. Four species at OSH, *Arabis drummondi* [*Boechera stricta*], *Carex versicaria*, *Dicanthelium boreale* [*Panicum boreale*] and *Poa trivialis,* which were inadvertently excluded from the county flora in 1996, are also included in Appendix 1.

DISCUSSION

The Wisconsin Natural Heritage Inventory (NHI) has established a working list (NHI 2016) that contains species known to be rare in the state that are legally

TABLE 1. Conservation Status of Rare Plants in Green Lake County, Wisconsin. Global ranks are G5 = Secure; G4 = Apparently Secure, and G3 = Vulnerable. Uncertainty about the exact status of a taxon is indicated by two ranks together (e.g., G4G5) or by "?". A "Q" after the global ranks indicates a questionable taxonomic assignment. In the case of taxa with infraspecific categories, the global rank of the full species is indicated by a "T" followed by a number. State ranks are S1 = Critically Imperiled; S2 = Imperiled; and S3 = Vulnerable. Source: Wisconsin Natural Heritage Working List (NHI 2016).

Name	Status	Global Rank/State Rank
Armoracia lacustris	Endangered	G4?/S1
Anticlea elegans var. *glauca*	Special Concern	G5T4T5/S2S3
Asclepias hirtella	Special Concern	G5/S2
Calamagrostis stricta	Special Concern	G5/S3
Carex festucacea	Special Concern	G5/S2
Cuscuta coryli	Special Concern	G5?/S1
Cuscuta pentagona	Special Concern	G5/S1
Cuscuta polygonorum	Special Concern`	G5/S1
Cypripedium candidum	Threatened	G4/S3
Eleocharis compressa	Special Concern	G4/S2
Eleocharis rostellata	Threatened	G5/S2
Epilobium strictum	Special Concern	G5?/S2S3
Galium brevipes	Special Concern	G4?/S1
Juglans cinerea	Special Concern	G4/S2S3
Juncus marginatus	Special Concern	G5/S2
Muhlenbergia richardsonis	Endangered	G5/S1
Opuntia fragilis	Threatened	G4G5/S3
Packera plattensis	Special Concern	G5/S3
Phemeranthus rugospermus	Special Concern	G3G4/S3
Platanthera flava var. herbiola	Threatened	G4T4Q/S2
Platanthera leucophaea	Endangered (Federally Threatened)	G2G3/S2
Polytaenia nuttallii	Threatened	G5/S2
Ranunculus cymbalaria	Threatened	G5/S2
Rhexia virginica	Special Concern	G5/S3
Rhus aromatica	Special Concern	G5/S1
Ruellia humilis	Endangered	G5/S2
Scleria triglomerata	Special Concern	G5/S2S3
Scleria verticillata	Special Concern	G5/S2
Sisyrinchium angustifolium	Special Concern	G5/S1
Triantha glutinosa	Threatened	G4G5/S2S3
Trichophorum cespitosum	Threatened	G5/S2
Triglochin palustris	Special Concern	G5/S3
Valeriana edulis var. ciliata	Special Concern	G5T3/S3

FIGURE 2. *Trillium recurvatum* Beck. Photo by Thomas L. Eddy.

designated as "Threatened" or "Endangered" (Wisconsin Natural Heritage Working List 2016). As required by Wisconsin State Statute 29.604 and Chapter NR 27 of the Wisconsin Administrative Code, the working list establishes the conservation status for state protected plants, animals, and lichens.

From field observations and herbaria specimens, plants suspected to be rare, but not threatened and endangered, are categorized by the NHI as "Special Concern." As with threatened and endangered plants, special concern species are periodically reviewed (generally every five years), and new evidence may warrant consideration for a status change.

Currently, a total of 33 species reported for Green Lake County are listed on the Threatened/Endangered species list. These include 25 species supported with vouchers at OSH and eight additional species listed in the OVFW. Among these are four endangered, eight threatened, and 21 special concern species. *Platanthera leucophaea*, state endangered, is also recognized as a federally threatened species. Table 1 summarizes the conservation status of these rare county flora, along with their global and state ranks. The NHI working list includes definitions of global and state ranks.

In Green Lake County, rare plants and their associates occur in diverse habitats, from prairies and oak openings to forests and wetlands, as well as rock outcrops and aquatic habitats. Rare species that are on the NHI working list and have been documented for the county since 1996 include *Ruellia humilis* (Endangered), *Ranunculus cymbalaria* (Threatened), and five Special Concern

FIGURE 3. *Ruellia humilus* Nutt. Photo by Thomas L. Eddy.

species, *Boechera missouriensis* [*Arabis missouriensis*], *Cardamine pratensis, Epilobium strictum, Juncus marginatus* and *Symphyotrichum robynsianum* [*Aster longifolius*].

The locally rare *Trillium recurvatum*, known from one location in the county (Eddy 2005a), was recently delisted as a Special Concern species (Figure 2). According to Thomas Meyer, conservation biologist at the Wisconsin Department of Natural Resources, "Wisconsin has many viable populations of this species" (personal communication 2012). Two other species, *Parthenium integrifolium* and *Gentiana alba*, were delisted from the NHI working list in 2014 due to their stable and somewhat expanding populations.

Seaside crowfoot, *Ranunculus cymbalaria* Pursh var. *cymbalaria*, is a state threatened species known from one location in the county (Eddy 2007). Although the species is locally rare, elsewhere in Wisconsin scattered populations flourish in damp ditches and railroad rights-of-way, as well as in street-side bluegrass lawns and mowed grassy highway strips, notably in the City of Superior, Douglas County (T. S. Cochrane, personal communication 2007). An informal consensus among state botanists holds that *R. cymbalaria* was likely introduced in Wisconsin, except possibly near Green Bay where older collections are reported (E. Judziewicz, personal communication 2012).

A record of the state endangered *Ruellia humilis* is known from one location in the county, a dry prairie remnant in the White River Marsh Wildlife Area (Figure 3). Although *R. humilis* has been successfully established on present-day prairie restoration sites and in native landscaped gardens, according to herbarium records the showy forb historically has a restricted distribution statewide (Eddy 2005b, 2006).

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APPENDIX 1. ADDITIONS TO THE VASCULAR FLORA OF GREEN LAKE COUNTY, WISCONSIN

This appendix includes all taxa of vascular plants for Green Lake County, Wisconsin that have been identified since publication of the county flora in 1996 (Eddy, 1996). Voucher specimens at the Neil A. Harriman Herbarium (OSH) were mainly collected and identified by the author, along with contributions made by other collectors. Also included are species reported from other herbaria in Wisconsin that are cited in the Online Virtual Flora of Wisconsin (OVFW) but are not currently represented at OSH.

The taxa are listed alphabetically by family, genus, and species, followed by collector(s) name(s) and voucher number, date collected, conservation status, and general location. In order to retain nomenclatural uniformity with Eddy (1996), families and binomials are those recognized by Gleason and Cronquist (1991). Family names and binomials that are recognized in OVFW (2017) are indicated by square brackets.

ACANTHACEAE

Ruellia humilis Nutt. (*Eddy and Harriman s.n.*) July 22, 2006, White River Wildlife Area. ENDANGERED

ACERACEAE [SAPINDACEAE]

Acer platanoides L. OVFW

Acer spicatum Lam. (*Eddy 4529*) June 21, 1997, Mitchell Glen

ADIANTACEAE [PTERIDACEAE]

Cryptogramma stelleri (S. G. Gmel.) Prantl OVFW

ALISMATACEAE

Alisma subcordatum Raf. (*Eddy 5081*) August 24, 2003, private farm, St. Marie Township

Sagittaria graminea Michx. var. *cristata* (Engelm.) Bogin. [*Sagittaria cristata* Engelm.] OVFW

S. rigida Pursh OVFW

ANACARDIACEAE

Toxicodendron rydbergii (Small ex Rydb.) Greene OVFW

APOCYNACEAE

Apocynum cannabinum L. (*Schultz s.n.*) July 1998, Fern Drive roadside

ASTERACEAE

Arnoglossum atriplicfolium (L.) H. Rob. (*Strohmeyer s.n.*) September 10, 2016

Aster drummondii Lindl. [Symphyotrichum drummondii (Lindl.) G. L. Nesom] OVFW

Aster longifolius Lam. [*Symphyotrichum robynsianum* (J.Rousseau) Brouillet & Labrecque] (*Czoschke s.n.*) September 19, 2015, White River Marsh Wildlife Area. SPECIAL CONCERN

A. macrophyllus L. [*Eurybia macrophylla* (L.) Cass.] (*Eddy 4617*) September 7, 1997, Mitchell Glen

A. ontarionis Wieg. [*Symphyotrichum ontarionis* (Wiegand) G. L.Nesom] (*Czoschke s.n.*) September 21, 2017, Green Lake Conference Center, Hammer Trail

A. puniceus L. [*Symphyotrichum puniceum var. puniceum* (L.) Á. Löve & D. Löve] (*Eddy and Ellis 4802*) September 9, 2000, Norwegian Bay Wetlands

A. sagittifolium Willd. [*Symphyotrichum urophyllum* (Lindl. Ex DC.) G. L.Nesom] OVFW

A. shortii Lindley. [*Symphyotrichum shortii* (Lindl.) G. L.Nesom] (*Eddy 4622, 4631*) September 26, 1997, Mitchell Glen

Bidens beckii Torr. ex Spreng. OVFW

B. comosa (A. Gray) Wieg. [*B. tripartita* L.] OVFW

B. coronata (L.) Britton [*B. trichosperma* (Michx.) Britton] OVFW

Boltonia asteroides (L.) L'Hér. var. *recognita* (Fernald & Griscom) Cronquist OVFW

Carduus acanthoides L. (*Eddy and Harriman s.n.*) July 21, 2009, private farm, Brooklyn Township

Lactuca serriola L. (*Eddy 4583*) August 18, 1997, Mitchell Glen

Rudbeckia laciniata L. OVFW

Solidago altissima L. OVFW

S. hispida Muhl. ex Willd. OVFW

Sonchus arvensis L. OVFW

S. asper (L.) Hill OVFW

BETULACEAE

Carpinus caroliniana Walter (*Eddy 5249*) June 24, 2016, private residence, Brooklyn Township

BIGNONIACEAE

Catalpa speciosa (Warder ex Barney) Warder ex Engelm. OVFW

BORAGINACEAE

Cynoglossum amabile Stapf & Drumm. (*Eddy 4603*) August 18, 1997, Mitchell Glen

Lithospermum incisum Lehm. OVFW

Myosotis verna Nutt. (*Harriman and Eddy 19687*) June 28, 1996, Utley Quarry

BRASSICACEAE

Arabis divaricarpa A. Nels. [*Boechera grahamii* (Lehm.) Windham & Al-Shehbaz] (*Roberts 024*) May 22, 2005, Snake Creek Wetlands Trail

A. drummondi A. Gray [*Boechera stricta* (Graham) Al-Shehbaz] (*Eddy and Harriman s.n.*) June 30, 1993, inadvertently excluded, Pine Bluff.

Cardamine pensylvanica Muhl. ex Willd. OVFW

C. pratensis L. (*Czoschke s.n.*) May 15, 2017, Snake Creek Wetlands Trail. SPECIAL CONCERN
Sinapis arvensis L. OVFW

BUTOMACEAE
Butomus umbellatus L. (*Lippert s.n.*) July 13, 2011, naturally established in backyard pond at private residence in the City of Berlin

CABOMBACEAE
Brasenia schreberi J. F. Gmel. OVFW

CANNABACEAE
Humulus lupulus L. (*Eddy 5076*) July 22, 2002, riprapped banks of Fox River, St. Marie Township

CAPRIFOLIACEAE
Lonicera dioica L. var. *glaucescens* (Rydb.) Butters. (*Eddy 5246*) April 28, 2012, Mitchell Glen
L. morrowii A.Gray OVFW
Symphoricarpos albus (L.) S. F. Blake (*Eddy 4614, 4629*) September 7, 1997, Mitchell Glen
S. occidentalis Hook. (*Eddy 4624*) October 5, 1997, Mitchell Glen

CAPRIFOLIACEAE [ADOXACEAE]
Viburnum rafinesquianum Schultes. var. *affine* (Bush) House. (*Eddy 4623*) October 5, 1997, Mitchell Glen

CARYOPHYLLACEAE
Silene csereii Baumg. OVFW
S. stellata (L.) W. T. Aiton OVFW
Stellaria media (L.) Vill. OVFW

CHENOPODIACEAE [AMARANTHACEAE]
Atriplex hastata L. [*Atriplex prostrata* Boucher ex DC.] OVFW
Chenopodium simplex (Torr.) Raf. OVFW
Salsola tragus L. OVFW

CISTACEAE
Lechea stricta Legg. ex Britton OVFW
L. tenuifolia Michx. OVFW

CUSCUTACEAE [CONVOLVULACEAE]
Cuscuta cephalanthi Engelm. OVFW
C. polygonorum Engelm. OVFW, SPECIAL CONCERN

CONVOLVULACEAE
Ipomoea purpurea (L.) Roth OVFW

CORNACEAE
Cornus alternifolia L.f. (*Eddy 5247*) April 28, 2012, Mitchell Glen
C. canadensis L. (*Eddy 4663*) July 2, 1998, White River Marsh Wildlife Area

CRASSULACEAE
Sedum purpureum (L.) J. A. Schultes [*Hylotelephium telephium* (L.) H. Ohba] OVFW

CYPERACEAE
Carex amphibola Steudel. [*Carex grisea* Wahlenb.] (*Eddy 4311*) June 8, 1997, Mitchell Glen
C. atherodes Spreng. OVFW
C. blanda Dewey. (*Eddy 4298, 4332, 4500*) June 8, 1997, Mitchell Glen; (*Eddy 5218*) June 4, 2009, private farm, Brooklyn Township
C. brunnescens (Pers.) Poir. subsp. *sphaerostachya* (Tuck.) Kalela OVFW
C. diandra Schrank. (*Eddy 5183*) August 4, 2003, White River Marsh Wildlife Area
C. disperma Dewey OVFW
C. haydenii Dewey OVFW
C. intumescens Rudge. (*Eddy s.n.*) July 30, 1997, White River Marsh Wildlife Area
C. lurida Wahlenb. OVFW

C. pellita Willd. OVFW
C. projecta MacKenzie (*Eddy 4475*) June 29, 1997, Mitchell Glen
C. vesicaria L. (*Eddy 1615*) June 25, 1989, damp roadside; (*Eddy and Ellis 4687*) June 1, 2000, Norwegian Bay Wetlands
Cyperus lupulinus (Spreng.) Marcks OVFW
Eleocharis ovata (Roth) Roemer &Schultes [*Eleocharis obtusa* (Willd.) Schult.] OVFW
Scirpus validus Vahl [*Schoenoplectus tabernaemontani* (C.C.Gmel.) Palla] OVFW

ELAEAGNACEAE
Elaeagnus angustifolia L. (*Eddy 5224*) June 3, 2009, private farm, Brooklyn Township

EQUISETACEAE
Equisetum pratense Ehrh. (*Eddy 4312, 4533*) June 8, 1997, July 11, 1997, Mitchell Glen

ERICACEAE
Chamaedaphne calyculata (L.) Moench. (*Eddy s.n.*) January 3, 1998, White River Marsh Wildlife Area
Epigaea repens L. OVFW

EUPHORBIACEAE
Euphorbia nutans Lag. OVFW

FABACEAE
Caragana arborescens Lam. (*Eddy 5256*) July 24, 2014, planted and spreading, Zobel County Park
Cercis canadensis L. (*Eddy 5255*) July 24, 2014, escape, Zobel County Park
Lathyrus ochroleucus Hook. OVFW

GENTIANACEAE
Centaurium pulchellum (Swartz) Druce. (*Eddy s.n.*) July 12, 1998, White River bridge roadside off County Trunk D; (*Eddy 4672*) September 20, 1998, Snake Creek Wetlands Trail
Gentiana rubricaulis Nutt. (*Eddy 5079*) August 24, 2003, private farm, St. Marie Township

GERANIACEAE
Erodium cicutarium (L.) L'Her (*Eddy 5211*) October 8, 2006, roadside

HAMAMELIDACEAE
Hamamelis virginiana L. (*Eddy 4529*) July 11, 1997, Mitchell Glen

HYDROPHYLLACEAE [BORAGINACEAE]
Hydrophyllum virginianum L. (*Eddy 5248*) April 28, 2012, Mitchell Glen

IRIDACEAE
Iris virginica var. *shrevei* (Small) E. S. Anderson OVFW
Sisyrinchium atlanticum E. P. Bicknell (*Eddy 520*) June 25, 1979, west of Snake Creek Wetlands Trail, off abandoned railroad right-of-way

JUNCACEAE
Juncus articulatus L. (*Eddy 5215*) July 20, 2007, Puchyan Marsh Road parking area
J. marginatus Rostk. (*Eddy 5202*) July 16, 2002, White River Marsh State Wildlife Area. SPECIAL CONCERN

LAMIACEAE
Mentha spicata L. OVFW

LEMNANCEAE [ARACEAE]
Lemna minor L. [*Lemna turionifera* Landolt] OVFW
Wolffia brasiliensis. Wedd. OVFW
W. papulifera C. H. Thomps. [*W. columbiana* H.Karst.] OVFW

LENTIBULARIACEAE
Utricularia intermedia Hayne. (*Eddy and Neil 4928*) July 6, 2001, Norwegian Bay Wetlands

LILIACEAE
Clintonia borealis (Aiton.) Raf. (*Eddy 5233*) May 21, 2009, White River Marsh Wildlife Area

LILIACEAE [MELANTHIACEAE]

Trillium cernuum L. (*Eddy 5234*) May 21, 2009, White River Marsh Wildlife Area

T. recurvatum Beck (*Eddy 5116*) May 13, 2005, Forest Avenue Oak Savanna

LYCOPODIACEAE

Lycopodium obscurum L. [*Dendrolycopodium obscurum* (L.) A. Haines] (*Eddy s.n.*) January 3, 1998, White River Marsh Wildlife Area

L. clavatum L. (*Eddy 4673*) November 7, 1998, White River Marsh Wildlife Area

NAJADACEAE [HYDROCHARITACEAE]

Najas guadalupensis (Spreng.) Magnus OVFW

N. marina L. OVFW

ONAGRACEAE

Circaea lutetiana L. [*Circaea canadensis* (L.) Hill] OVFW

Epilobium leptophyllum Raf. (*Eddy 5178*) August 4, 2003, White River Marsh State Wildlife Area

E. strictum Muhl. (*Eddy 5175*) August 4, 2003, White River Marsh State Wildlife Area. SPECIAL CONCERN

Ludwigia alternifolia L. (*Eddy and Lyon 5257*) September 10, 2017, private property approximately 1.6 miles northwest from City of Princeton, edge opening of swampy aspen woods

L. polycarpa Short & R. Peter OVFW

Oenothera laciniata subsp. *laciniata* Hill OVFW

Oenothera biennis var. *canescens* L. [*O. villosa* Thunb.] OVFW

OPHIOGLOSSACEAE

Botrychium matricariifolium A. Brun. (*Eddy 4268*) September 13, 1996, Eddy residence at 426 Walker Avenue, Green Lake

OXALIDACEAE

Oxalis dillenii Jacq. OVFW

POACEAE

Anthoxanthum hirtum (Schrank) Y. Schouten & Veldkamp OVFW

Aristida dichotoma var. *curtissii* A. Gray OVFW, SPECIAL CONCERN

Dichanthelium acuminatum (Sw.) Gould & C. A. Clark OVFW

D. boreale (Nash) Freckmann (*Underwood 816*) July 9, 1978, inadvertently excluded, Puchyan Marsh; (*Eddy 4354*) June 21, 1997, Mitchell Glen

Eragrostis frankii C. A. Mey. ex Steud. OVFW

Festuca octoflora Walter OVFW

Lolium pratense (Huds.) Darbysh. OVFW

Milium effusum L. (*Eddy 4542*) July 11, 1997, Mitchell Glen

Muhlenbergia schreberi J. F. Gmel. OVFW

Panicum philadelphicum Bernh. ex Trin. (*Eddy 2001*) August 24, 1980, Utley Quarry

Poa glauca Vahl. (*Eddy and Ellis 4695*) September 2, 2000, Norwegian Bay Wetlands

P. trivialis L. (*Eddy 1641*) July 18, 1980, Green Lake Conference Center

POLEMONIACEAE

Phlox divaricata L. (*Eddy 4244*) May 17, 1997, Mitchell Glen

POLYGONACEAE

Polygonum achoreum S.F.Blake OVFW

Persicaria hydropiper L. [*Persicaria hydropiper* (L.) Spach] OVFW

POTAMOGETONACEAE

Potamogeton pectinatus L. [*Stuckenia pectinata* (L.) Börner] OVFW

P. pusillus L. [*Potamogeton berchtoldii* Fieber] OVFW

PRIMULACEAE

Lysimachia lanceolata Walter (*Eddy 5158*) August 4, 2003, White River Marsh Wildlife Area

L. vulgaris L. (*Eddy and Neil 4929*) July 6, 2001, Norwegian Bay Wetlands

RANUNCULACEAE

Coptis trifolia (L.) Salisb. (*Eddy 5208*) April 30, 2003, White River Marsh Wildlife Area
Ranunculus cymbalaria Pursh var. *cymbalaria* (*Eddy 5213*) June 29, 2007, Puchyan Marsh Road parking area. THREATENED
R. trichophyllus Chaix (in part) [*R. aquatilis* var. *diffusus* With.] OVFW

RHAMNACEAE

Rhamnus alnifolia L'Hér. OVFW

ROSACEAE

Agrimonia pubescens Wallr. OVFW
Crataegus crus-galli L. (*Eddy 5080*) August 24, 2003, private farm, St. Marie Township
C. succulenta Schrad. ex Link OVFW
Fragaria vesca var. *americana* Porter [*Fragaria vesca* subsp. *americana* (Porter) Staudt] OVFW
Geum laciniatum Murray OVFW
Rubus occidentalis L. (*Eddy 4337*) June 21, 1997, Mitchell Glen
R. odoratus L. (*Eddy 5209*) June 27, 2006, Green Lake Conference Center
Potentilla intermedia L. (*Eddy 4888*) June 16, 2001, Norwegian Bay Wetlands

RUBIACEAE

Galium concinnum T. & G. (*Eddy 4473*) June 29, 1997, Mitchell Glen
G. tinctorium L. OVFW

SALICACEAE

Salix amygdaloides Andersson OVFW
S. petiolaris Sm. OVFW

SCHROPHULARIACEAE [OROBANCHACEAE]

Agalinis purpurea (L.) Pennell var. *parviflora* (L.) Pennell [*Agalinis paupercula* (A.Gray) Britton] OVFW

SCROPHULARIACEAE [PLANTAGINACEAE]

Penstemon grandiflorus Nutt. (*Eddy 5210*) August 1, 2006, White River Marsh Wildlife Area
P. pallidus Small OVFW, SPECIAL CONCERN
Veronica arvensis L. (*Rill 4303*) June 25, 1977, Berlin Oakwood Cemetery; (*Eddy 4276*) June 1, 1997, Mitchell Glen

SOLANACEAE

Solanum carolinense L. (*Eddy 5207*) September 5, 2005, private farm, St. Marie Township
S. nigrum L. [*S. ptychanthum* Dunal] OVFW

TAXACEAE

Taxus canadensis Marsh. (*Eddy 4509*) July 5, 1997, Mitchell Glen

THYMELAEACEAE

Dirca palustris L. (*Eddy 4649*) June 25, 1998, Mitchell Glen

ULMACEAE

Ulmus rubra Muhl. (*Eddy 4601*) August 18, 1997, Mitchell Glen

URTICACEAE

Laportea canadensis (L.) Wedd. (*Eddy 4597*) August 18, 1997, Mitchell Glen

VIOLACEAE

Viola conspersa Reichenb. [*V. labradorica* Schrank] OVFW
V. macloskeyi F.E.Lloyd OVFW
V. nephrophylla Greene. (*Eddy and Ellis 4806*) September 9, 2000, Norwegian Bay Wetlands
V. selkirkii Pursh (*Eddy 4819*) May 23, 2001, Norwegian Bay Wetlands
V. sororia Willd. (in part) [*Viola affinis* Leconte] OVFW

VITACEAE

Parthenocissus vitacea (Knerr) Hitch. [*Parthenocissus inserta* (A. Kern.) Fritsch] OVFW

NOTEWORTHY COLLECTIONS

NEW AND INTERESTING INTRODUCED VASCULAR PLANTS FOR ONTARIO AND CANADA

Colin J. Chapman
Atlantic Canada Conservation Data Centre
146 Main Street
Sackville, New Brunswick E4L 1A8

James S. Pringle
Royal Botanical Gardens
680 Plains Road West
Burlington, Ontario L7T 4H4

Allium tuberosum Rottler ex Spreng.
Amaryllidaceae
Chinese Chives

Significance of the report. This southeast Asian species is new to the spontaneous flora of Ontario and Canada.

Previous Knowledge. *Allium tuberosum* is cultivated in China, Siberia, and North America, often for culinary uses, and less frequently as an ornamental (McNeal and Jacobsen 2002; J. Peter, personal communication). It has been reported as occasionally escaping to disturbed areas and roadsides in Michigan, Ohio, Wisconsin, Nebraska, and New England (McNeal and Jacobsen 2002; Vincent et al. 2011; Voss and Reznicek 2012).

Discussion. The specimens here discussed, as well as all those in the following accounts, are the basis for the county records in the list of the vascular plants of Ontario's Carolinian Zone (Oldham 2017). In 2016 C.J. Chapman collected a clear escape from a vacant lot in the City of Hamilton; a subsequent search of larger Ontario herbaria (TRT, DAO, CAN, HAM) produced two additional specimens. The apparent first spontaneous record of *Allium tuberosum* in Ontario was collected in 1975 by J. Nyman from a vacant lot in the Greater Toronto Area. Originally identified as *A. stellatum* Fraser ex Ker Gawl., it was redetermined as *A. tuberosum* by Michael J. Oldham in March 2017. This species was subsequently collected in 2012 from Haldimand-Norfolk County by J. Schlegel. The question now arises whether these records represent waifs or persistent populations. In 2015 *A. tuberosum* was found persisting in a former cultural site at Royal Botanical Gardens (RBG) that has been unmaintained since the mid-1990s. Its persistence at the vacant site indicates that the species is able to over-

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winter in southern Ontario. Multiple records of spontaneous *A. tuberosum* also suggest that this species has been overlooked, potentially due to its status as an urban weed. Urban areas understandably receive less botanical attention than natural areas, and for this reason we speculate that it may have escaped more often than is reported.

Diagnostic Characters. *Allium tuberosum* is easily distinguished by its white flowers on erect pedicels that bloom from late August into October, much later than other Ontario species of *Allium* L. (Voss and Reznicek 2012). *Allium stellatum*, with which the first record was confused, has purple flowers that face in all directions (Voss and Reznicek 2012).

Specimen Citations. Ontario. Greater Toronto Area; Corner of Denlow Blvd. and Banbury Rd. on south side. Don Mills. Latitude: 43°45′N, Longitude: 79°21′W. Disturbed vacant lot and adjoining fence-lines and sidewalks. September 20, 1975. *Judy Nyman s.n.* (TRT).

Haldimand-Norfolk County: Lake Erie shore at foot of Rte. 12 (Fisherville Road). between hamlets of Rainham Centre and Selkirk. Crack in boulder breakwall between beach and road. In full sun. Small clump with strong onion smell. Flowers white, midveins of tepals greenish and inconspicuous in life. Additional clumps further east along breakwall. Latitude: 42°49.321′N, Longitude: 79°52.838′W. Associates: *Acer negundo, Dipsacus fullonum, Solidago canadensis, Cichorium intybus, Coronilla varia*. August 30, 2012. *J. Schlegel 1203* (HAM).

Halton Regional Municipality: Southern edge of Hendrie Valley Sanctuary, adjacent to Unsworth Avenue HV-2015-Polygon 6. Upland mixed cultural site. Garden unmaintained since mid-1990s, exotic herbs/shrubs/trees persisting. Seeded in 2014 with native meadow species. UTM NAD83 17T 591963 4794688 ± 70m. August 27, 2015. *N. Cavallin, R. M. Godfrey, C. J. Chapman, C. Burt s.n.* (HAM).

City of Hamilton: southwest corner of Wilson Street and Mary Street. Vegetated corner of parking lot; one clump; on very narrow and isolated strip of soil. Latitude: 43°15′27.7″N, Longitude: 79°51′47.5″W. Associates: *Convolvulus arvensis*, *Cichorium intybus*, *Lotus corniculatus*, *Setaria viridis*, *Plantago lanceolata*. September 28, 2016. *C. J. Chapman 2016-157* (HAM).

Cercidiphyllum japonicum Siebold & Zucc. ex J.J. Hoffm. & J.H. Schult. bis
Cercidiphyllaceae
Katsura

Significance of the report. The first record of *Cercidiphyllum japonicum* as an escape from cultivation in Ontario and Canada.

Previous Knowledge. *Cercidiphyllum japonicum* is a dioecious tree native to deciduous forests in China and Japan (Knees 2011). In North America, it has been reported as escaping from cultivation in Massachusetts, Connecticut, New York, Pennsylvania, and Ohio (Haines 2011; USDA, NRCS 2016). Sato et al. (2006) report a maximum seed dispersal distance of more than 300 meters. Cercidiphyllaceae is a monotypic family with a distinctive morphology; APG IV

(2016) currently places it within the Saxifragales, but others have suggested placing it in its own order (e.g., Swamy and Bailey 1949).

Discussion. Iwanycki et al. (2014) report finding escapes in Cootes Paradise Sanctuary in 2010 and taking a specimen in 2011. We have not been able to locate such a specimen in either the HAM collection or its database. In 2016, several seedlings measuring up to 45 cm in height were discovered at the forest edge of Royal Botanical Gardens' Cootes Paradise Sanctuary. The young *C. japonicum* observed were approximately 45 meters from the nearest cultivated female individual. A focused search of the vicinity provided no evidence of seedling establishment within the forest itself. The first author verified reliable images for an additional report of *C. japonicum* from Nordheimer Ravine, Toronto. The roughly three-feet-tall seedlings appeared in imported soil, although it is unclear whether they were locally escaped from cultivation or transported in the soil as weeds (J. Routh, personal communication). It seems likely that an increased use of *C. japonicum* in landscaping should result in the discovery of additional escapes from cultivation. Nearly all escapes from cultivation have thus far been found in ruderal habitats; however, the escape observed by Iwanycki et al. (2014) was reportedly discovered along a trail in a deciduous forest. In its native range, *C. japonicum* is a tree of deciduous forests; it should be monitored in the Great Lakes region for escape into high-quality natural habitat.

Diagnostic Characters. *Cercidiphyllum japonicum* has distinctive dimorphic leaves. Mature leaves of short shoots have a morphology similar to those of *Cercis* L., demonstrating the etymology of the generic name. However, they are oppositely arranged and smaller than the leaves of *Cercis*, which are alternate. Leaves on short shoots are cordate and with crenate margins, while long shoots bear leaves with a shallowly crenate to entire margin. Blade shape varies from elliptic to ovate to deltoid. For a detailed discussion of morphology, see Swamy and Bailey (1949).

Specimen Citation. Ontario. City of Hamilton: On forest edge between Lilac Dell and Cootes Paradise Sanctuary. Four seedlings observed in immediate area. Latitude 43°16′56.7″N, Longitude 79°54′18.6″W. June 20, 2016. *C. J. Chapman, J. E. Thompson, and P. Becker 2016-137* (HAM).

Corydalis nobilis (L.) Pers.
Papaveraceae
Siberian Corydalis

Significance of the report. This species is not known to the spontaneous flora of North America (Stern 1997).

Previous Knowledge. *Corydalis nobilis* is a perennial endemic of central Asia-Siberia, where it inhabits stony slopes and shaded ravines (Shulkina 2004). In Europe *C. nobilis* is reported as naturalized in Sweden and Finland (Jalas and Suominen 1991). Cullen (2011) notes that *C. nobilis* is likely the most frequently grown of the taller *Corydalis* species.

Discussion. *Corydalis nobilis* was collected from Royal Botanical Gardens' Woodland Garden in the spring of 2016, prompted by its abundance throughout the cultural forest. It was first collected from this location in April 2009 by A.

Scovil, N. Iwanycki, and H. Crochetiere, but was treated as a cultivated specimen. However, there is no record of *C. nobilis* having been acquired by RBG, and its provenance is unknown. The population has been spreading aggressively by seed in recent years, prompting staff to manage it intensively to prevent its migration into Hendrie Valley Sanctuary (C. Briggs, personal communication). Regardless of its method of introduction, it is now a persistent garden weed on RBG property. The aggressive reseeding of *C. nobilis* is similar to that of *C. incisa* (Thunb.) Pers., a recently reported invasive species in the States of New York, Virginia, West Virginia, Maryland, Tennessee, Washington D.C., and Pennsylvania (Atha et al. 2014; USDA, APHIS 2017). For this reason, botanists are urged to promptly report new records to landowners.

Diagnostic Characters. The flowers of *Corydalis nobilis* are arranged in a dense inflorescence and have a yellow corolla with dark violet colouration at the tip (Figure 1) (Cullen 2011). The four native species of *Corydalis* in the Great Lakes region—*C. aurea* Willd., *C. curvisiliqua* Engelm. ex A. Gray, *C. flavula* (Raf.) DC., *C. micrantha* (Engelm. ex A. Gray) A. Gray—generally do not exhibit this colouration, and they have sparser inflorescences (Stern 1997; Cullen 2011). It is also distinguished from its native, annual/biennial congeners by its robust perennial habit (Stern 1997; Zhang et al. 2008). *Corydalis solida* (L.) Clairv. (Michigan, Ontario) and *C. incisa* (New York), two extremely rare introduced species, are both distinguished from *C. nobilis* by their purple corollas (Voss and Reznicek 2012; Atha et al. 2014).

Specimen Citations. Ontario. Halton Regional Municipality: Woodland Garden. Colour code: RHS 1966, Flowers: Yellow-orange group 17C. Identified by Jim Pringle on May 22 2009. 29 April 2009. *A. Scovil, N. E. Iwanycki, and H. Crochetiere s.n.* (HAM).

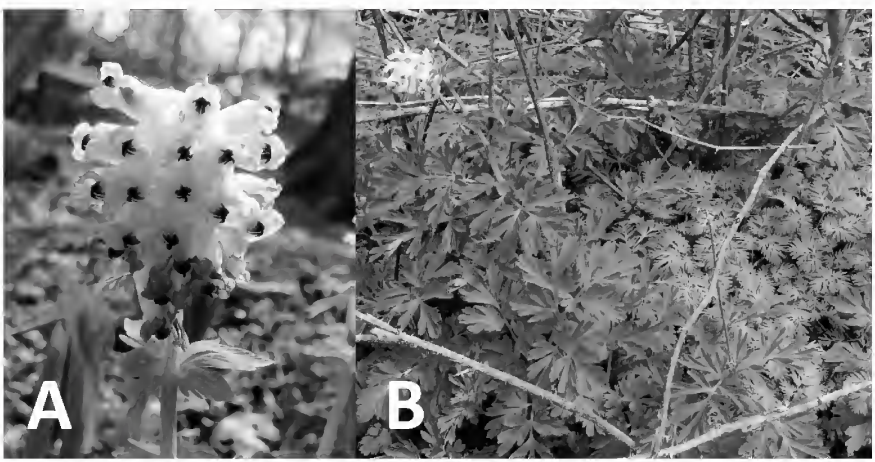

FIGURE 1. A: Inflorescence of *Corydalis nobilis* (L.) Pers. Note the dense arrangement of flowers and the dark colouration at the tip of the corollas. B: *Corydalis nobilis* (flowering) competing with *Dicentra canadensis* (Goldie) Walp., which has smaller leaves with paler colouration. Photos by Philippa Becker.

Halton Regional Municipality: Royal Botanical Gardens. Woodland Garden, bottom of slope before the gate to Hendrie Valley Sanctuary. Found throughout the Woodland Garden on north-facing slope, down to the lowland and Rifle Range before the gate to Hendrie Valley. Latitude 43°17′33.1″N, Longitude 79°52′40.0″W. Associates: *Rosa multiflora, Dicentra canadensis*. May 10, 2016. *C. J. Chapman, J. E. Thompson, and P. Becker 2016-15* (HAM, DAO).

Sorbus intermedia (Ehrh.) Pers.
Rosaceae
Swedish Whitebeam

Significance of the report. The second Great Lakes region report of *Sorbus intermedia*, an extremely rare escape from cultivation.

Previous Knowledge. *Sorbus intermedia* is a medium-sized apomictic tree native to northern and eastern Europe (Warburg and Kárpáti 1968). It is one of a number of species that are widely used in gardening and landscaping for its flowers, decorative fruit, and foliage (Warburg and Kárpáti 1968; McAllister and Taylor 2011). In Canada, it is reported as very rarely escaping to disturbed habitats in British Columbia (Brouillet et al. 2010+, Zika and Bailleul 2014). In the United States, *Sorbus intermedia* is reported as escaping in Massachussets, and Washington (Zika and Bailleul 2014).

Discussion. A single shrub of *Sorbus intermedia* was discovered in 2006 by Michael Oldham and Sam Brinker in deciduous woods in the Regional Municipality of Niagara. The identity of the specimen was verified by Peter Zika in 2012. Two additional sterile escapes from cultivation were collected from disturbed habitats near railroad tracks in Niagara in 2007 and in the City of Hamilton in 2016. *C. J. Chapman 2016-156* is approximately 750 meters from the closest known cultivated street tree at Stinson Street and Erie Avenue. The cultivated individual was observed with abundant fruit set in the fall of 2016. In its native range, *S. intermedia* is dispersed by thrushes and waxwings (Rushforth 1999). Likewise, birds may have dispersed the seeds of this apomictic tree in Hamilton, which plausibly explains its movement to the Escarpment Rail Trail. It seems likely that *S. intermedia* will escape in additional counties in the Great Lakes region where it is cultivated.

Diagnostic Characters. Unlike those of most familiar Ontario *Sorbus* species, the leaves of *S. intermedia* are nearly simple, with numerous lobes rather than leaflets (Figure 2) (McAllister and Taylor 2011). It shares this feature with *S. hybrida* L., another rare introduction in northeastern North America (Brouillet et al. 2010+; Haines 2011). In general, *S. intermedia* is distinguished from *S. hybrida* by its leaf morphology: in the latter the basalmost pair of lobes are dissected to the midrib; however, separate basal lobes may also occur on sucker shoots of *S. intermedia* (McAllister and Taylor 2011). The leaves are also distinguished by the number of lateral vein pairs: 7–9 in *S. intermedia*, 10–12 in *S. hybrida* (McAllister and Taylor 2011).

Specimen Citation. Ontario. Regional Municipality of Niagara. Deciduous woods. Whirlpool area, Niagara River. Single sterile shrub at edge of rocky trail through woods; almost certainly non-planted. UTM NAD83 17T 657293

FIGURE 2. Leaf of *Sorbus intermedia* (Ehrh.) Pers. on a long shoot with the two basal lobes dissected to the midrib. Note fewer than nine pairs of lateral veins. Photo by Colin J. Chapman.

4776326. July 18, 2006. *M. J. Oldham 32980* (MICH, WTU, herb. M. J. Oldham).

Regional Municipality of Niagara. Niagara Falls Railway Yard, between Whirlpool Road and Victoria Avenue. Disturbed ground along railway tracks. Single 10 ft tall shrub; sterile. UTM NAD83 17T 655972.2756 4776568.5. August 17, 2007. *M. J. Oldham and S. Brinker 34927* (WTU, NHIC).

City of Hamilton: Woodland south of Escarpment Rail Trail. Disturbed woodland next to wet depression. One plant in this locality, roughly 110 cm tall; two additional plants were found within 100m, both smaller and in similar habitat. Latitude 43°14′39.2″N, Longitude 79°50′51.9″W. Associates: *Rhamnus cathartica*, *Populus alba*, *Rhus typhina*, *Toxicodendron radicans*, *Solidago canadensis*, *Symphyotrichum lanceolatum*, *Rosa multiflora*, *Fraxinus pennsylvanica*, *Dactylis glomerata*, *Ageratina altissima*, *Alliaria petiolata*, *Ambrosia artemisiifolia*. September 19, 2016. *C. J. Chapman 2016-156* (HAM).

ACKNOWLEDGMENTS

Michael Oldham provided collection data for his Niagara *Sorbus intermedia* records, the Toronto *Allium tuberosum* record, and searched TRT, CAN, and DAO for the taxa here reported. We are very grateful for his help. We also thank Charlie Briggs, Jon Peter, and John Routh for their comments.

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NOTEWORTHY COLLECTIONS

JUNCUS VALIDUS COVILLE (JUNCACEAE) NEW TO THE GREAT LAKES REGION

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Significance of the Report. The first reports of this species from the Great Lakes region, including Ohio and Michigan.

Previous knowledge. *Juncus validus* Coville (roundhead rush) is a perennial wetland generalist of the south-central and southeastern United States. Prior to 1900, the species was known from a relatively restricted area of Oklahoma, Texas, Arkansas, and Louisiana, with one outlying (and likely non-native) population in Mississippi. From this putative natural range, *J. validus* has since spread east and north across the southeastern United States to Maryland and Delaware (Knapp 2014). These eastern populations have been conflictingly interpreted as native and of conservation concern (Kentucky and North Carolina) or as non-native (Delaware, Maryland, and Virginia) (NatureServe 2017). Rangewide, *J. validus* is considered globally secure (G5) by NatureServe (2017).

Discussion. Two small patches of *Juncus validus* were documented in 2008 along a moist to dry sandy road created by off-road trucks in Lucas County, Ohio. The population persisted through 2009 and was not found in 2010. In 2011, a new population of 70 plants was found approximately 300 meters from this location in a palustrine sand plain wetland created in 2010. This population expanded to over 100 plants in 2015. The species has not reappeared in the original location, which has become much drier and is apparently no longer periodically saturated.

In 2015, a large population of *Juncus validus* was documented in a disturbed, wet railroad right-of-way in Berrien County, Michigan. This is approximately 241 km (150 mi) WNW of the Ohio populations and 600 km (370 mi) NE of the nearest previously documented population in Alexander Co., Illinois (*R. Mohlenbrock* 18991, MO).

The recent documentation of *Juncus validus* in Ohio and Michigan follows similar discoveries of this species over the past several decades at localities east

FIGURE 1. The inflorescence of *Juncus validus* showing the nearly spherical or spherical heads, which are similar to but larger than those of the rare native *J. scirpoides*. Photo by B.S. Slaughter.

and north of its apparent native range (Knapp 2014). However, the Ohio and Michigan populations are considerably disjunct, both from the putative native range and from each other, and suggest that the species may be present but overlooked elsewhere in the Upper Midwest.

Diagnostic Characters. *Juncus validus* is placed in *Juncus* sect. *Ozophyllum* (= subg. *Septati*), the largest section in the genus, which is characterized by perfectly septate leaves and by flowers that lack subtending bracteoles (Brooks and Clemants 2000; Knapp 2014). *Juncus validus* can be identified by its combination of rhizomatous stems; laterally compressed leaves; spheric or nearly spheric, many-flowered heads; flowers with three stamens and largest tepals 4–5 mm long; capsules exserted or slightly included with valves separating at dehiscence into three distinct portions at the apex; and clear, untailed, yellow-brown seed bodies (Brooks and Clemants 2000; Knapp 2014). In the Great Lakes region, *J. validus* (Figure 1) is most likely to be confused with *J. scirpoides* Lam., from which it differs in its larger mature heads (12–15 mm vs. 7–12 mm diameter), longer tepals (3.5–4.5 mm vs. 2–3 mm), longer capsules (4.5–5.5 mm vs. 3–4 mm), and lack of tuberous rhizomes (MICHIGAN FLORA ONLINE 2011).

Specimen Citations. Ohio. Lucas County: NE ¼ Sec 12, T07N R09E. Two small clumps each with ca. 20 plants. Edge of palustrine sandy depression, 70 percent vegetated. 0.45 miles north of Salisbury Road and 0.44 miles west of Crissey Road. 41.589258, –83.769717. Associates: *Ludwigia palustris*, *Juncus*

biflorus, *Fimbristylis autumnalis*, *Panicum rigidulum*, *Populus deltoides* seedlings, *Eleocharis acicularis.* September 2, 2008. *Walters 14448* (MICH, CLM).

Michigan. Berrien County: NW¼ Sec. 20, T07S R20W. Scattered colonies on disturbed peaty sand and clay in right-of-way between railroad and Red Arrow Hwy just S of Barker Ln. 41.853517, -86.660564. Associates: *Eleocharis elliptica*, *Gentianopsis crinita*, *Juncus tenuis*, *J. torreyi*, *Linum medium*, *Lythrum salicaria*, *Sorghastrum nutans*, *Thelypteris palustris*. September 1, 2015. *Slaughter 1521* (MICH). Det. A.A. Reznicek March 17, 2016.

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NOTEWORTHY COLLECTION

MICHIGAN

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Petasites hybridus (L.) G. Gaertn., B. Mey. & Scherb.
Asteraceae
Butterfly dock, common butter bur

Significance of the Report. The third Michigan collection record of this highly invasive non-native species.

Previous Knowledge. *Petasites hybridus* is native to Europe and central Asia, where it grows along riverbanks and other damp places. In northern Europe, as well as in areas where it has been introduced near the edge of its range, female individuals of *P. hybridus* are absent or rare. It is likely this plant spreads through its complex rhizomatous growth (Dingwall 1976).

For centuries, *Petasites hybridus* has been used as a medical plant for migraines and as a remedy for hay fever due to its rich suite of sesquiterpene phytochemicals (Saritas et al. 2002; Lipton et al. 2004). Within its native range, there is a diverse geographical distribution of these sesquiterpenes as well as of a suite of alkaloids that varies between populations. As a result of this phytochemical variation, some populations are more frequently used as a source of medicinals that others (Chizzola et al. 2002). In addition to their medicinal uses, these phytochemicals play an important role in defense from herbivory (Hägele et al. 1998).

Petasites hybridus has been introduced locally across eastern North America, likely due to its medicinal properties and to the horticultural value of its unusually large leaves. Naturalized populations have been recorded from 10 different states within the United States, most of which are documented in the Midwest and northeast (USDA, NRCS 2017). In Michigan, there are only two documented locations, one in Eaton County in the south-central portion of the Lower Peninsula, and the other in Marquette County in the Upper Peninsula (Voss and Reznicek 2012). In both counties the plant has spread aggressively. For instance, the banks of tributaries near the Dead River in Marquette, Michigan, as well as several miles of roadsides, are dominated by *P. hybridus*. In the last 15 years this plant has spread throughout the city of Marquette and Marquette Township and has become a management priority for local conservation groups. There are also additional scattered reports of this plant across Michigan in the Midwest Inva-

FIGURE 1. *Petasites hybridus* growing along the West Branch of the Flat River, Montcalm County, Michigan. This is one of two large colonies in this population that is growing on the edge of private property into the state game area. Photo by Michael C. Rotter.

sive Species Information Network database (MISIN 2017). The degree of naturalization of these plants is unknown but may represent additional source populations for further invasion.

Discussion. *Petasites hybridus* was found along the west branch of the Flat River in Montcalm County, Michigan within the Langston State Game Area (43°17′43.43″N, 85°15′47.31″W) near Hunter Lake during the summer of 2016 (Fig. 1). The population was found growing abundantly and seemed to be spreading from a location on private residential property. Discussions with the previous home owners revealed that it was planted as an ornamental and spread after dumping yard waste into the flood plain (the landowner mentioned that the plants were "taking over the garden"). The former owners obtained the plants from a private land owner in Muskegon, Michigan and planted them because of their unusually large leaves. Escape from cultivation is likely the main source of establishment in North America. For this reason, Wisconsin, for example, has listed *P. hybridus* as a prohibited species (WDNR 2017).

Petasites hybridus is highly invasive in most conditions such that it is able to easily outcompete other plants for resources. In particular, its large leaves shade out other species, and its aggressive vegetative growth make it a potential threat to wetlands in eastern North America. Surveillance is important for detecting this species early before it has a chance to take over natural areas and for controlling new populations. Additionally, educating the public about the ecological threats this plant poses to native plants and working with land owners will help to counter widespread planting of this species.

Diagnostic Characters. In Michigan, *P. hybridus* can be recognized by its large leaves (up to 1m across) that resemble those of cultivated rhubarb (Fig 2).

FIGURE 2. A leaf of *Petasites hybridus.* The large size is reminiscent of the unrelated cultivated rhubarb. Photo by Michael C. Rotter.

Plants can grow up to 6 feet high and form a dense canopy. Flowers are produced in early spring before the foliage, and the inflorescences consist of spikes of pink-purple flowers. *Petasites hybridus* can be distinguished from the native *P. frigidus* (L.) Fries and *P. sagittatus* (Pursh) A. Gray by its pink-purple flowers, in contrast to the creamy-white flowers of the native species. The leaves of *P. hybridus* are much larger than those of either of the native species. *Petasites japonicus* (Siebold & Zucc.) Maxim. is another cultivated species that may escape cultivation and has been found in Ontario and the Pacific Northwest (Kartesz 2015). *Petasites hybridus* can be distinguished from *P. japonicus* by the regularly dentate lobes on *P. hybridus*.

Specimen citation. Montcalm County. Observed on private property and found to be spreading into state land along the west branch of the Flat River near Hunter Lake. 43°17′43.43″N, 85°15′47.31″W. Large leaves (up to 1m wide) present, but only small leaves collected. Leaves collected on August 17, 2016, and flowers collected on March3, 2017. Several large patches (each about 10m in area) were observed spreading in seep areas and along the Flat River. Associated species: *Acer saccharum, Fraxinus americana, Caltha palustrus, Fagus grandifolia. Rotter 717* (MICH).

ACKNOWLEDGMENTS

I would like to thank my parents, Judy and Mike Rotter, for sending specimens and monitoring the population for me while I was out of state. Thanks to Michael Huft and Emily Mydlowski for reviewing this note.

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ISOBEL DICKINSON MEMORIAL AWARD RECIPIENT

Congratulations to **Emily A. Mydlowski**, who was the recipient of the Isobel Dickinson Memorial Award for **best student-authored paper** published in *The Great Lakes Botanist*, Volume 56. The selected paper was entitled "A Note on Mucilage and Herbivore Damage on *Brasenia schreberi* in a Northern Michigan Lake" by Emily Mydlowski and Michael Rotter, The Great Lakes Botanist 56: 45–51. We acknowledge the Michigan Botanical Club—Dickinson Award Committee for evaluation of the student papers and the Michigan Botanical Foundation for funding this award.

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Refer to http://quod.lib.umich.edu/m/mbot/submit for more detailed instructions, especially for formatting, style conventions, literature cited, and voucher specimen requirements. Please contact the editor with any questions.

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9. Manuscripts must be submitted electronically to the email address of the editor. All manuscripts will be reviewed by at least two referees.

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On the cover: Black spruce (*Picea mariana*) stand at Mud Lake, Livingston County, Michigan. Photo by Ben Spei.